Half Hours with the Microscope.

Illustrated

Page

HALF-HOURS WITH THE MICROSCOPE.

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HALF-HOURS

WITH

THE MICROSCOPE;

BEING

A POPULAR GUIDE

TO THE USE OF THE MICROSCOPE

AS A MEANS OF

AMUSEMENT AND INSTRUCTION.

ILLUSTRATED FROM NATURE,

BY

TUFFEN WEST.

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AND ALL BOOKSELLERS.

DESCRIPTION OF PLATES.

In the examination of these Plates the observer is requested to remember that they are not all drawn to the same scale. Some objects, adapted for low powers, are only magnified a few times, whilst smaller objects are magnified many hundred times. All objects, of course, vary in apparent size, according to the powers with which they are examined. Descriptions of the objects will be found in the pages indicated.

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HALF-HOURS WITH THE MICROSCOPE.

CHAPTER I.

A HALF-HOUR ON THE STRUCTURE OF THE MICROSCOPE.

THE Microscope is often regarded as merely a toy, and only capable of affording a certain amount of amusement. However true this might have been when its manufacture was less perfectly understood, it is now an instrument of so much importance, that scarcely any other can vie with it in the interest of its discoveries. By its means man increases the power of his vision, so that he thus gains a greater knowledge of the nature of all objects by which he is surrounded. What eyes would be to the man who is born blind, the Microscope is to the man who has eyes. It opens a new world to him, and thousands of objects whose form and shape, and even existence, he could only imagine, can now be observed with accuracy.

Nor is this increase of knowledge without great advantages. Take for instance the study of plants and animals. These beings are endowed with what we call life: they grow and perform certain living functions; but as to the mode of their growth, and the way in which their functions were performed, little or nothing was known till the Microscope revealed their minute structure, and showed how

their various parts were related to each other. The Microscope has thus become a necessary instrument in the hands of the botanist, the physiologist, the zoologist, the anatomist, and the geologist.

Let us, then, endeavour to understand how it is this little instrument has been of so great service in helping on the advancement of science. Its use depends entirely on its assisting the human eye to see—to see more with its aid than it could possibly do without it. This it does in two ways; first by enabling the human eye to be brought more closely in contact with an object than it otherwise could be, and secondly by magnifying the object looked at.

Just in proportion as we bring our eyes close to objects, do we see more of them. Thus, if we look at a printed bill from the opposite side of a street, we can see only the larger letters; but if we go nearer we see the smaller letters, till at last we get to a point when we can see no more by getting closer. Now suppose there were letters printed on the bill so small that we could not see them with the naked eye, we could yet, by the aid of a lens—a piece of concave or convex glass,—bring our eyes nearer to the letters, and see. It would depend entirely on the form of the lens, as to how close we could bring our eyes to the print and see; but this great fact will be observed, that the nearer we can get our eyes to the print, the more we shall see. The most important part of a Microscope, then, consists of a lens, by means of which the eye can be brought nearer to any object, and is thus enabled to see more of it. Magnifying-glasses and Simple Microscopes consist mainly of this one element. In order, however, to enable the eye to get as close as possible to an object, it becomes convenient to use more than one lens in a glass through which we look. When these lenses are fixed in a brass tube,

and attached to the Simple Microscope, they are called doublets and triplets. The magnifying-glasses which are made to be held in the hand, frequently have two or three glasses, by which the power of the instrument may be increased or decreased. Such instruments as these were the first which were employed by microscopic observers; and it is a proof of the essential nature of this part of the Microscope, that many of our greatest discoveries have been made with the Simple Microscope.

The nearer the glass or lens is brought to an object, so as to enable the eye to see, the more of the object will be seen. So that when we use a glass which enables us to see within one inch of an object, we see much more than if we could bring it within only an inch and a half or two inches. So on, till we come to distances so small as the eighth, sixteenth, or even twentieth of an inch.

Although a great deal may be seen by a common hand-glass, such as may be purchased at an optician's for 7*s.* 6*d.* or half a guinea, yet the hand is unsteady, and if they were made with a very short focus, it would be almost impossible to use them. Besides, it is very desirable in examining objects, to have both hands free. On these accounts the glasses, which in such an arrangement are called *object-glasses*, are attached to a *stand* and placed in an arm which moves up and down with rack-work. In this way, the distance of the object from the glass can be regulated with great nicety. Underneath the glass, and attached to the same stand, is a little plate or framework, to hold objects, which are placed on a piece of glass. This is called *the stage*. Sometimes rack-work is added to this stage, by which the objects can be moved upon it backwards and forwards, without being moved by the hand. Such an arrangement as this is called a

Simple Microscope. Of course many other things may be added to it, to make it more convenient for observation ; but these are its essential parts.

But, although the Simple Microscope embraces the essential conditions of all Microscopes, and has, in the hands of competent observers, done so much for science, it is, nevertheless, going out of fashion, and giving way to the *Compound Microscope.* Although this instrument is much more complicated, as might be inferred from its name, than the Simple Microscope, it is now constructed with so much accuracy, that it can be used with as great certainty and ease as the Simple Microscope itself. In order to understand its construction, we must study the nature of the lens of which we have been speaking. If we take a lens, and hold it against an object on one side, and place a piece of white paper on the other side, we shall find that, at a certain point, a picture of the object will be produced on the paper. This is the way in which pictures are produced by the camera, of which the photographic artist avails himself for his portraits and sun-drawings. This picture of the object, then, exists in the air at a certain point beyond the lens. Now, this picture may be looked at by another glass, of the same character as the first ; and by this means the object is brought in a very enlarged form to the eye. Now, this is the principle involved in the Compound Microscope. In order to effect this object, a *tube* (generally a brass tube) is fitted to the object-glass, and at the upper part of this tube a glass is fitted on, called an *eye-piece.* The eye-piece consists generally of two lenses, the object of which is to bring the picture in the tube to a condition in which it can be seen by the eye as readily as it could through the object-glass itself. It is obvious that such an arrangement as this has great advan-

tages over the simple Microscope. In the first place, by the use of the lenses in the eye-pieces, the object may be magnified to almost any extent. There is, however, a limit to the utility of this magnifying power; for when objects are greatly magnified, they become indistinct. This is seen in the Oxhydrogen and Solar Microscopes, where the objects are thrown by means of highly magnifying lenses on a white sheet; and, although made enormously large, their details are much less clear than when looked at by a lens magnifying much less.

Compound Microscopes are generally fitted up with two eye-pieces, one shallow and the other deep. The first has its lenses close together, and magnifies the most, whilst the other has them further apart, and magnifies less. In the use of these eye-pieces, it should never be forgotten that the one which magnifies least is generally the most trustworthy.

The Compound Microscope is now, undoubtedly, one of the most perfect instruments invented and used by man. In the case of all other instruments, the materials with which they are made, and the defects of construction, are drawbacks on their perfect working; but, in the Compound Microscope, we have an instrument working up to the theory of its construction. It does actually all that could be expected from it, upon a correct theory of the principles upon which it is constructed. Nevertheless, this instrument did not come perfect from its inventor's hands. Its principles were understood by the earlier microscopic observers in the seventeenth and eighteenth centuries, but there were certain drawbacks to its use, which were not overcome till the commencement of the second quarter of the present century.

These drawbacks depended on the nature of the

lenses used in its construction. The technical term for the defects alluded to, are *chromatic* and *spherical aberration.* Most persons are acquainted with the fact, that when light passes through irregular pieces of cut glass—as the drops of a chandelier—a variety of colours are produced. These colours, when formed by a prism, produce a coloured image called the *spectrum.* Now, all pieces of glass with irregular surfaces produce, more or less, the colours of the spectrum when light passes through them; and this is the case with the lenses which are used as object-glasses for Microscopes. In glasses of defective construction, every object looked at through them is coloured by the agency of this property. The greater the number of lenses used in a Microscope, the greater, of course, is the liability to this colouring. This is chromatic aberration; and the liability to it in the earlier-made Compound Microscopes was so great that it destroyed the value of the instrument for purposes of observation.

Again, the rays of light, when passing through convex lenses, do not fall — when they form a picture — all on the same plane; and therefore, instead of forming the object as presented, produce a picture of it that is bent and more or less deformed. This is spherical aberration, and a fault which was liable to be increased by the number of glasses, in the same way as chromatic aberration. This also occurred in Compound Microscopes; and the two things operated so greatly to the prejudice of this instrument, that it was seldom or never used.

Gradually, however, means of improvement were discovered. These defects were rectified in telescopes; and at last a solution of all the difficulties that beset the path of the Microscope-maker was afforded by the discoveries of Mr. Joseph Jackson

Lister, a gentleman engaged in business in London, who, in a paper published in the *Philosophical Transactions* for 1829, pointed out the way in which the Compound Microscope could be constructed free from chromatic and spherical aberration.

It is this instrument, then, which is most commonly employed at the present day, and to which we are indebted for most of the recent progress in microscopic observation. Its essential parts, in addition to those we have seen in the Simple Microscope, are the tube and the eye-piece. Its advantage over the simple instrument not only consists in its magnifying power, but also in the facility with which it may be employed, in consequence of the more favourable distance the eye of the observer is from the object observed.

In using the Microscope, a great variety of accessory apparatus may be employed to facilitate the various objects which the observer has in view. As this is a book for beginners, we shall only mention a few of these.

Every Microscope is generally supplied with small slips of glass, three inches long and one inch wide. These are intended to place the objects on, which are to be examined. They are either used temporarily or permanently with this object in view, and are called *slides*. When used temporarily, an object, such as a small insect or part of an insect, is placed upon the middle of it ; and it may be either placed immediately upon the stage at the proper distance from the object-glass, or a drop of water may be placed on the slide and a piece of thinner glass placed over the object. This is the most convenient arrangement, as you may then tilt your Microscope without the slide or object falling off.

Objects, when placed under the Microscope, are of two kinds,—either *transparent* or *opaque.* When they are opaque, they may either be placed upon the slips of glass, or put between a small pair of *forceps* which are fixed to the stage of the Microscope, and the light of a window or lamp allowed to fall upon them. This is not, however, sufficient, generally, to examine things with great accuracy ; and an instrument called a *condenser* is provided for this purpose. It consists merely of a large lens, which is sometimes fixed to the stage, or has a separate stand. Its object is to allow a concentrated ray of light to be thrown on the opaque object whilst under the object-glass of the Microscope. This is called viewing objects by *reflected light.*

Transparent objects, on the other hand, are viewed with *transmitted light :* and here again the natural diffused light of day, or of a lamp, is not sufficient ; so that all Microscopes are provided beneath the stage with a *mirror*, plane on one side and concave on the other. The object of this mirror, which is called the reflector, is to catch the rays of light and concentrate them on the object under the Microscope. The rays of light thus pass through the object, and its parts are seen much more clearly.

Another convenient piece of apparatus is an *animalcule-cage.* This consists of a little brass box, inverted, to the bottom of which is attached a piece of glass. Over this, again, is placed a lid or cover, with a glass top. The cover can be made to press on the glass beneath, and an object being placed between the two glasses, can be submitted to any amount of pressure thought necessary. This is a very important instrument for examining minute crustacea, animalcules, zoophytes, and other living

and moving objects, especially when they live in water.

In the use of the cage and the slide, care must be taken not to break them, by turning the object-glass down upon them. The tube is provided with rack-work and a handle, by which it moves; so that the object-glass may be adjusted to any distance from the object. It is sometimes a difficult thing, when the object-glass has a focus of not more than a quarter or eighth of an inch, to adjust it to exactly the point at which the object is best seen, by means of the coarse handles on the rack-work; and the Microscope is often provided with what is called a *fine adjustment*, by means of which the object-glass is moved down on the object in a much slower and more gradual manner. Care, however, must always be taken lest the object-glass is brought down on to the object or slide, so as to break them. In some cases the lens of the object-glass itself has been broken in this way. Your incautious friends who have never seen a Microscope before, and have sufficient confidence in themselves to attempt to command a man-of-war, though they were in one for the first time, will frequently turn your Microscope up and down with a force sufficient to crack your lens. Such friends should, if possible, be kept from the table till the instrument is ready for them to take a peep, and then it is best to request that they will keep their hands behind them.

The picture of the object brought to the eye in the Compound Microscope is always the wrong end upwards. That is, the picture is always the reverse in the Microscope to what it is with the naked eye. You need constantly to be aware of this, especially if you are going to dissect an object under the Microscope, as your right hand becomes left, and

your left right. The observer, however, soon gets accustomed to this, and it creates no difficulty ultimately. But science constantly attends on the Microscope, and ministers to its slightest defects. A little instrument called an *erector*, composed of a lens which reverses the picture once more, is supplied by the optician, and can be had by those who practise the refinements of microscopic observation.

Another instrument which will be found of considerable service even to the beginner with the Microscope, is a *micrometer*. This is an instrument for measuring the size of objects observed. Exaggerated notions about the smallness of objects are very prevalent; and as it is almost impossible to say accurately how small an object is without some means of measuring, a Micrometer becomes essential where accuracy is desired. This is effected by having some object of known size to compare with the object observed. The most convenient instrument of this kind is a glass slide, on which lines are drawn the hundredth and thousandth of an inch apart. If this slide, which is called a *stage micrometer*, is laid over an object, or the object placed upon it, its relation to the ruled lines will be easily seen, and the size computed accordingly. Many other forms of micrometer have been invented, but this is one of the simplest and most easily used.

It is a good plan to make drawings of all objects examined, or at any rate those which are new to the observer. A note-book should be kept for this purpose, and what cannot at once be identified by the object, may afterwards be so by the drawing. All persons, however, have not the gift of drawing, and for those who need assistance in this way, the *camera lucida* has been invented. This instru-

ment is applied to the tube of the Microscope when placed at right angles with the stem, in such a way that a person looking into it sees the object directly under his eye, so that he may easily draw its form on a piece of paper placed underneath.

Amongst the accessory apparatus, are various arrangements for concentrating the light on the objects which are placed for examination under the Microscope. Amongst these combinations, is one called the *achromatic condenser*. This consists of a series of lenses, which are placed between the mirror and the stage, and which may consist of an ordinary object-glass. The stages of the larger kinds of Microscopes are fitted up with a screw or slide, by which the condenser can be fastened beneath and adjusted to the proper focus for throwing light on the object examined. Instruments have also been invented, called *illuminators*, which are intended to supplement or assist the mirror in throwing light on the object. These are things, however, about which the beginner need not trouble himself. They are amongst the apparatus which contribute to the perfection of the Microscope, but are not amongst its necessary accompaniments.

The same may be said of the *polarizing apparatus*. The use of polarized light adds greatly to the beautiful appearance of many objects under the Microscope, but it is only in a very few instances in which it can be said to furnish a means of distinguishing one object from the other. It may, therefore, be left to the time when the observer has gone through some little practice with his instrument, or has saved enough money to buy the necessary apparatus.

Having said thus much with regard to apparatus, we will now give some directions for the

use of the Microscope under ordinary circumstances. The Microscope may be either used by the light of the sun in the daytime, or at night by some form of artificial light. It is best used by daylight, as artificial light is more likely to tire the eyes.

Having determined to work by daylight, some spot should be selected near a window, out of the direct light of the sun, in which to place a small, firm, steady table. On this the Microscope should be placed, and the object-glass should be screwed on to the tube. The mirror should be then adjusted so as to throw a bright ray of light on to the object-glass. The eye-piece having been previously placed at the top of the tube, the Microscope is now ready to receive a transparent object. If the object to be examined is an animalcule, it may be conveyed to the animalcule-cage by means of a glass tube, which should be dipped into the water where the object is contained, with the finger covered over the upper orifice, so that no air can escape. By taking the finger off when the tube is in the water, the fluid will rush into the tube, and with it the object to be examined. The finger is again applied to the top of the tube, and the fluid obtained conveyed to the animalcule-cage : only such a quantity of the water should be allowed to fall out of the tube on to the cage as will enable the observer to put on the cover of the cage without pressing the fluid out at the sides of the cage. If the water is thus allowed to overflow, it runs over the glasses of the cage, and thus obscures the vision. An object or objects having been thus placed in the cage, it is conveyed to the stage, and placed in such a position that the ray of light passing from the mirror to the object-glass may pass through it. This having been done, the observer must now

place his eye over the eye-piece, and use the screw in the tube, and move the object-glass downwards until he gets a clear view of objects moving in the water. This is called *focussing*. The glass may then be moved up or down, in order that the best view of the object may be obtained. When the object-glass is one of high power, the *fine adjustment*, which is attached to most compound instruments, may be used for this purpose. When the proper focus is obtained, the object may be moved up or down, right or left, with the hand, or by the aid of the screws which are employed in the various forms of what are called *movable stages*.

When objects not requiring the live-box or animalcule-cage are to be observed, they may be transferred to the glass slide, by aid of a thin slip of wood, or a porcupine-quill moistened at the end, or by a pair of small *forceps*. Some transparent objects may be seen without any medium, but generally it is best to place them on the slide with a drop or two of clean water, which may be placed on it with a *dipping-tube*. When water is used, it will generally be found best to cover the object with a small piece of thin glass. Small square pieces of thin glass are sold at all the opticians' shops for this purpose. The object is then placed under the object-glass as before.

In order to render objects transparent, so that they may be viewed by transmitted light, very thin sections of them should be made. This may be effected by means of a very sharp scalpel, or a razor. When objects are too small to be held in the hand to be cut, they may be placed between two pieces of cork, and a section of them made at the same time that the cork is cut through.

Sometimes it is found desirable to unravel an

object under the Microscope. If this is the case, only a low power should be used, and the object may be placed on a glass slide, without any glass over, and two needles with small wooden handles employed—ordinary sewing needles, with their eyes stuck in the handle of a hair-pencil, will answer very well. Even when dissection is not to be carried on under the Microscope, a pair of needles of this sort, for tearing minute structures in pieces, will be found very useful.

When opaque objects are to be examined, the light from the mirror may be shut off, and the aid of the bull's-eye condenser called in. The object being secured in the forceps attached to the stage or laid upon a slide, the light is allowed to fall on it through the condenser. The object-glass must be focussed in the same manner as for transparent objects, till the best distance is secured for examining it. The petals of plants, the wings and other parts of insects, with many other objects, can only be examined in this way.

Even the beginner will find it useful to keep by him some little bottles, containing certain chemical re-agents. Thus, a *solution of iodine* is useful to apply to the tissues of plants, for the purpose of ascertaining the presence of starch. This solution may be made by adding five grains of iodine and five grains of iodide of potassium to an ounce of distilled water. Strong *sulphuric acid* will be found useful in rendering soft the tissues of both plants and animals; and in conjunction with iodine it is a test for the presence of cellulose. The *strong solution of potash* (liquor potassæ) can also be employed with advantage in softening and making clear opaque animal and vegetable substances. *Nitric acid* has even a greater solvent power than sulphuric acid, and may be used for the same

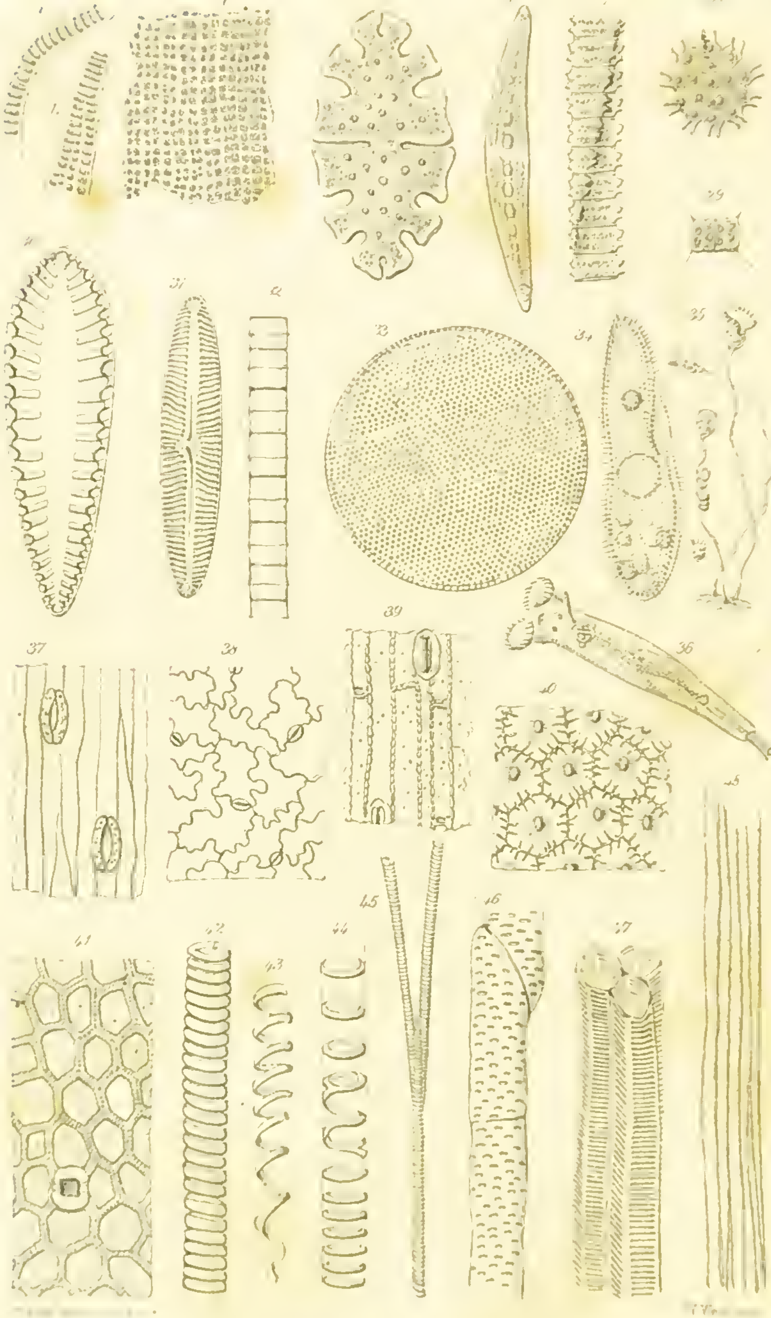
purposes. At the same time, the use of these powerful acids requires care, as, if they get on to the object-glass, or it is exposed long to the action of their vapours, its transparency may become impaired.

CHAPTER II.

A HALF-HOUR WITH THE MICROSCOPE IN THE GARDEN.

Amongst the objects which can be examined by the Microscope, none are more easily obtained than plants. All who have a Microscope may not be fortunate enough to have a garden; but plants are easily obtained, and even the Londoner has access to an unbounded store in Covent Garden. We will, then, commence our Microscopic studies with plants. On no department of nature has the Microscope thrown more light than on the structure of plants; and we will endeavour to study these in such a manner as to show the importance of the discoveries that have been made by the aid of this instrument.

If we take, now, a portion of a plant, the thin section of an apple, or a portion of the coloured parts of a flower, or a section of a leaf, and place it, with a little water, on a glass slide under the Microscope, we shall see that these parts are composed of little roundish hollow bodies, sometimes pressed closely together, and sometimes loose, assuming very various shapes. These hollow bodies are called "cells," and we shall find that all parts of plants are built up of cells. Sometimes, however, they have so far lost their cellular shape that we cannot recognize it at all. Nevertheless, all the parts we see are formed out of cells. Cells tolerably round, and not pressed on each other, may be seen in most pulpy fruits. In fact, with a little care in making a thin section, and placing



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it under the Microscope, the cellular structure of plants may be observed in all their soft parts.

If, now, we take a thin section from an apple, or other soft fruit, or from a growing bud, or tuberous root, as the turnip, we shall find that many of the cells contain in their interior a "nucleus," or central spot (Fig. 1, Pl. 1). This nucleus is a point of great importance in the history of the cell, for it has been found that the cell originates with it, and that all cells are either formed from a nucleus of this kind, or by the division of a thin membrane in the interior of the cell, which represents the nucleus, and is called a "primordial utricle."

When the cells of plants have thus originated, they either remain free or only slightly adherent to each other, or they press upon each other, assuming a variety of shapes; they then form what is called a "tissue." When cells are equally pressed on all sides, they form twelve-sided figures, which, when cut through, present hexagonal spaces (Fig. 2, Pl. 1). This may be seen in the pith of most plants, more especially the common elder. Transverse slices of the stems of any kind of plant from the garden may be made by a razor, or sharp pen-knife, and will afford interesting objects for the Microscope.

Cells, during their growth, assume a variety of shapes, and the tissues which they form are named accordingly (Figs. 232, 234, Pl. 8). Sometimes the cells are very much elongated, or they unite together, to form an elongated tube; the tissue thus formed is called "vascular tissue;" but where the cells retain their primitive form, it is called "cellular tissue." A very interesting form of the latter is the "stellate" tissue found in most water-plants, and especially regularly developed in the common rush (Fig. 3,

Pl. 1). The object of this tissue is, evidently, to allow of the existence of a large quantity of air in the spaces between the cells; by which means the stem of the plant is lightened, and it is better adapted for growth in water.

If the leaf of any plant is examined, it will be found that on the external surface there is a thin layer, called, after the thin external membrane in animals, the "epidermis." This layer is composed of very minute cells—smaller than those in other parts of the plant, and when placed under the Microscope, presents a variety of forms (Figs. 37, 38, 39, 40, 41, Pl. 2) of cellular tissue. There is, however, a peculiar structure in this layer, which is found on the outside of all parts of plants, which demands attention. In the midst of the tissue, at very varying distances, are placed little openings, having a semilunar cell on each side. These openings are called "stomates," and can be well seen in the leaf of the hyacinth, where the cells of the epidermis are transparent; but the little cells which form the stomate are filled with green colouring-matter (Fig. 37, Pl. 2). The stomates vary very much in size and in numbers. They are found in larger numbers on the lower than on the upper side of leaves. In the common water-cress they are very small, and the cells of the epidermis are sinuous (Fig. 38, Pl. 2). The stomates are found on all plants having an epidermis. In Figs. 39 and 41 they are represented from the wheat and the aloe. In the latter plant the cells of the cuticle are very much thickened. They can also be seen on the cuticle of the fruit (Fig. 231, Pl. 8) and the petals. This part of the plant forms a beautiful object under the Microscope. The petal of the common scarlet geranium (*Pelargonium*) affords a beautiful instance of the way in which the cells of plants

become marked, by their peculiar method of growth (Fig. 40, Pl. 2).

The vascular tissue of plants is either plain or marked in its interior. If we examine the ribs of leaves, the green stems of plants, or a longitudinal section of wood, elongated fibres, lying side by side, are observed (Fig. 48, Pl. 2). This is what is called "ligneous" or "woody" tissue, and the greater part of the wood and solid parts of plants are composed of this tissue (Fig. 239, Pl. 8). The fibres lie in bundles, and are divided from each other by cellular tissue. This latter, in the woody stems of trees, constitutes the "medullary rays," which are seen in transverse sections of stems, extending from the pith to the bark. The difference observable in the distribution of the woody fibres and the medullary rays renders the examination of transverse sections of the stems of plants a subject of much interest (Figs. 51, 52, 53, Pl. 3). In the transverse sections of stems of most plants, large open tubes are observed (Fig. 51, Pl. 3). These are called "ducts." Such ducts may be well observed in the transverse section of the common radish (Fig. 46, Pl. 2) and other roots. These ducts are often marked by pores, or dots, and are hence called "dotted ducts." These dots are the result of deposits in the interior of the tube of which the duct is formed, and a great variety of such markings are found in the interior of vascular tissue. One of the most common forms of marked vascular tissue is that which is called glandular woody tissue (Fig. 49, Pl. 3). This kind of tissue is found in all plants belonging to the cone-bearing, or fir tribe of plants. In order to discover it, recourse need not be had to the garden for growing plants, as every piece of furniture made of deal wood will afford a ready means of obtaining a specimen. All that is necessary to

observe the little round disks with a black dot in the middle, is to make a thin longitudinal section of a piece of deal, and place it under a half or quarter-inch object-glass, when they will be readily apparent. The application of a drop of water on the slide, or immersing them in Canada balsam, will bring out their structure better.

If we take the leaf-stalk of a strawberry or of garden rhubarb, and make a transverse section all round, nearly to the centre of the stalk, the lower part will at last break off, but be still held to the upper by very delicate threads. If we examine these threads, we shall find that they are fibres (Fig. 43, Pl. 2), which have been left by the breaking of the vessel in which they were contained. These vessels are called "spiral vessels," and are found in the stems and leaves of many plants (Fig. 42, Pl. 2). Sometimes these vessels are found branched, as in the common chickweed (Fig. 45, Pl. 2). Occasionally the spiral fibre breaks, or is absorbed at certain points, leaving only a circular portion in the form of a ring (Fig. 44, Pl. 2). Such vessels are called "annular," and may be observed in the roots of growing wheat; also in the leaves of the garden rhubarb. A modification of this kind of tissue is seen in the stems and roots of ferns, in which the vessel assumes a many-sided form (Fig. 47, Pl. 2). Sometimes the spiral fibre is free (Fig. 240, Pl. 8).

The bark as well as the wood of trees affords the same appearance under the Microscope. If a piece of the bark of any plant be examined by means of a very thin transparent section, and placed upon a slide, and put under an inch or a half-inch object-glass, the structure of the bark may be easily seen. On the outside of all is the cuticle, or epidermis, and under this lie two layers, composed, like the

cuticle, of cellular tissue; but the inner layer, before we come to the wood of the stem, is composed of woody tissue. The cellular layer next the woody one is often enveloped to a very great extent, and then constitutes what we know by the name of cork. The bark from which corks are made is obtained from an oak-tree, which grows in the Levant. If we make a very thin section of a cork, its cellular structure can be easily made out. The cells are almost cubical, and when submitted to the action of a little solution of caustic potash, they may frequently be seen to be slightly pitted (Fig. 54, Pl. 3).

Many of the structures which are described above may be seen in common coal; thus proving most satisfactorily that this substance has been formed from a decayed vegetation (Figs. 55, 56, Pl. 3). The examination of coal, however, is by no means an easy task, and the hands and fingers may be made very black, and the Microscope very dirty, without any evident structure being made out. Some kinds of coal are much better adapted for this purpose than others. Sections may be made by grinding, or coal may be submitted to the action of nitric acid till it is sufficiently soft to be cut. The amateur will not find it easy work to make sections of coal; but should he wish to try, he may fasten a piece on to a slip of glass with Canada balsam, and when it has become firmly fixed, he may rub it down on a fine stone till it is sufficiently thin to allow its structure to be seen under the Microscope. Coal presents both vascular and cellular tissue. The vascular tissue is, for the most part, of the glandular woody kind; thus leading to the inference that the greater portion of the vegetation that supplied the coal-beds belonged to the family of the firs.

The external forms of the tissues of plants having been examined, we are now prepared to regard their contents. In the interior of the cells forming the roots and the growing parts of plants, will be observed a number of minute grains, generally of a roundish form. If we make a thin slice of a potato, these granules may be very obviously seen, lying in the interior of the cells of which the potato is composed (Fig. 59, Pl. 3). If we now take a drop of the solution of iodine, and apply it to these cells full of granular contents, we shall find that the granules assume a deep-blue colour. This is the proof that they are starch; and as far as we at present know, no other substance but starch has the power of assuming this beautiful blue colour under the influence of iodine. We have thus a ready means at all times of distinguishing starch. The grains of starch are of various sizes and shapes. The starch of the flour of wheat has a round form, and varies in size (Fig. 57, Pl. 3); that of the oat is characterized by the small granules of starch adhering together (Fig. 58, Pl. 3) in globular shapes. When these globules are broken up, the grains appear very irregular. In the arrow-root called "Tous les Mois" the grains are very large (Fig. 60, Pl. 3), and, like those of the potato, they look as if composed of a series of plates laid one upon the other, gradually becoming smaller to the top. These lines do not, however, indicate a series of plates, but rather a series of contractions of a hollow vesicle or bag. This vesicular character of starch may be made apparent by gently heating it, after moistening, over a spirit-lamp on a glass slide, or by dropping on it a drop of strong sulphuric acid. Sago (Fig. 62, Pl. 3) and tapioca (Fig. 63, Pl. 3) are almost entirely composed of starch, and may be easily examined

under the Microscope. The starch granules are insoluble in water, but they are easily diffused through it; so that by washing any vegetable tissue containing starch, with water, and pouring it off and allowing it to stand, the starch falls to the bottom. In this way the various kinds of starches may be procured for microscopical examination. The granules of starch have frequently a little black irregular spot in their centre. In the starch of Indian corn it assumes the form of a cross (Fig. 61, Pl. 3). Starch is a good object for the use of the polarizing apparatus, which can be applied to most compound Microscopes. The grains of starch, under the influence of polarized light, become coloured in a beautiful and peculiar manner, permitting of great variation, as in the case of all polarized objects.

If we take a little of the white juice from the common dandelion, and put it under the Microscope, we shall often see, besides the globules of caoutchouc which makes the juice milky, crystals of various forms. Such crystals are called by the botanist "raphides,"—signifying their needle-like form. They arise from the formation and accumulation of insoluble salts in the fluids of the plant. They are seen in various plants, and under very different circumstances. Beautiful needle-like crystals can be seen in the juice of the common hyacinth (Fig. 64, Pl. 3), which may be obtained by pressing. A question has been raised as to whether they are always formed *in* the cell. They are mostly found lying in the cell, as in the leaves of the common aloe (Fig. 65, Pl. 3): they may also be seen in the tissues of the common squill, and in the root of the iris. If a thin section of the brown outer coat of the common onion is made, small prismatic crystals are observed (Fig. 67, Pl. 3). Sometimes

several of these crystals unite together around a central mass, forming a stellate body. These bodies have been called "crystal glands," but they have no glandular properties. They may be seen in the root and leaf-stalk of common rhubarb (Fig. 66, Pl. 3), and may be easily observed in a bit of rhubarb from a spring tart. These crystals are mostly formed of oxalate of lime. They are constantly found in plants producing oxalic acid. The gritty nature of rhubarb-root arises from the presence of oxalate of lime. Sometimes the oxalate of lime assumes a round disk-like form. Such forms are seen in plants belonging to the cactus family (Fig. 68, Pl. 3).

Other substances, besides oxalate of lime, are found crystallized in the interior and on the surface of plants. Crystals of sulphate of lime have been found in the interior of cycadaceous plants. Carbonate of lime is found in crystals on the surface of some species of *Chara*, or stonewort. There is a shrub not uncommon in gardens, known by the name of *Deutzia scabra*, on the under surface of the leaves of which there are beautiful stellate crystals of silica. The best way of seeing these is to put the leaf under the Microscope, and to examine it by the aid of reflected light. Sugar and honey also assume a crystalline form, and may be known by the shape of their crystals (Figs. 228, 229, 230, Pl. 8).

The external surface of the parts of all plants will afford a rich field of amusement and instruction to the microscopic observer. The cuticle, or epidermis, of which we have before spoken, has a very varied structure, and contains the little openings, stomates, before described. The cuticle, which, in a large number of cases, is smooth, becomes elevated in some instances, and forms a series of projections,

which, according to their form, are called "papillæ," "warts," "hairs," "glands," and "prickles." The papillæ are slight elevations, consisting of one, two, or more cells; the warts are larger and harder; whilst the hairs are long; the glands contain a secretion; and the prickles are hard and sharp. For examining the form and growth of these hairs, the flowers of the common pansy (heart's-ease) afford a good object. Some of the projections are merely papillæ (Fig. 70, Pl. 3); others are found longer, and more like hairs (Fig. 71, Pl. 3); whilst others are long, and as the sides of the hair have contracted, they have the appearance of a knotted stick (Fig. 73, Pl. 3). The family of grasses, wheat, barley, oats, and other forms, are favourable subjects for the examination of simple hairs (Fig. 69, Pl. 3), or hairs composed of a single elongated cell. All that is necessary to be done, in order to see these hairs, is to take any part of the plant where they are present, and to slice off a small portion with a sharp penknife or razor, and place it under the Microscope. They may be either examined dry, or a little water may be added, and a piece of thin glass placed over them on the slide. Hairs are frequently formed of several cells. On the white dead-nettle the hairs are composed of two cells (Fig. 74, Pl. 3). The nucleus, or cytoblast, is often seen in these, as represented in Figs. 71, 72, and 74, Pl. 3. On the common groundsel hairs may be seen, composed of several cells, each cell containing a nucleus (Fig. 75, Pl. 3). Hairs like a string of beads are found on the pimpernel and sow-thistle (Fig. 76, Pl. 3). Occasionally hairs become branched. Thus, on the leaf of the common chrysanthemum the hairs present the form of the letter T (Fig. 78, Pl. 3). On the under-surface of the leaves of the common shepherd's purse, and the bramble, hairs are

seen with several branches, giving them a stellated appearance (Fig. 79, Pl. 3). These hairs may be examined as opaque or transparent objects, when immersed in a little glycerine. The hair of the tobacco-plant presents a peculiar knobbed appearance (Fig. 77, Pl. 3). The presence of these hairs is said to be the test of the purity of tobacco. Sometimes hairs are covered over with little dots, which are supposed to be deposited after the growth of the cells of the hair. Such hairs may be seen in the common verbena (Fig. 80, Pl. 3). Occasionally an elevation, consisting of several cells, is formed at the base of a hair (Fig. 81, Pl. 3). When these cells contain a poisonous secretion, which is transmitted along the tube of the hair, the hair is called a glandular hair, or sting. Such are the hairs of the common stinging-nettle (Fig. 82, Pl. 3).

The hairs constituting the down or "pappus" of compositous plants assume a variety of forms. The seed or fruit of the common groundsel has a beautiful crown (Fig. 235, Pl. 8). The pappus of the dandelion appears notched (Fig. 236). The burdock has a cottony hair (Fig. 237), while the goats-beard is like a feather (Fig. 238).

If a hair is examined in its growing state, with an object-glass of one quarter of an inch focus, a movement of the particles in its interior is often observed. This is easily seen in the hairs around the stamens of the common Spiderwort (*Tradescantia Virginica*). Such movements are very common in the cells of water-plants. One of those most commonly cultivated in aquaria at the present day, the *Valisneria spiralis*, affords the best example of this interesting phenomenon. In order to observe this movement, a growing leaf of the valisneria should be taken, and a longitudinal slice should be removed from its surface, by means of a

sharp penknife or razor. The slice, or the sliced part left on the leaf, should now be put on a slide, a drop or two of water added, and covered with a thin piece of glass, when, after a little time, especially in a warm room, the movement will be observed (Fig. 83, Pl. 3). This movement may also be seen in the leaves of the new water-weed (*Anacharis alsinastrum*), the frog-bit, the rootlets of wheat, and in the family of charas. In examining the last, the external bark, or rind, should be removed from the cells, or the movements will not be seen. This movement seems dependent on the internal protoplasmic matter which is contained in all cells, and which in these cases appears to be spread over the interior of the cell. It is, however, capable of contraction, and when the plants are exposed to cold, the protoplasmic matter contracts and prevents the movement of the contents in the interior. It is, apparently, the extension of this substance beyond the walls of the cell which constitutes the little hair-like organs called "cilia," which are constantly moving, and by the aid of which the spores of some plants effect rapid movements (Figs. 13 and 14, Pl. 1). The effect of these cilia in producing the movements of plants is well seen in the *Volvox globator* (Fig. 14), which, on account of its rapid movements, was at one time regarded as an *animalcule*, but it is now known to be a plant. Cilia are, however, more frequently met with in the animal kingdom.

Amongst the parts of plants which can alone be investigated by the Microscope, are the stamens. These organs are situated in the flower, between the petals and the pistil, and usually consist of a filament, or stalk, with a knob or anther at its top. If the anther is examined, it will usually be found to consist of two separate valves, or cases, in each of

which is contained a quantity of powder, or dust, called "pollen." The walls of these valves are worth careful examination under the Microscope, on account of the beautifully-marked cellular tissue of which their inner walls consist. The cells of this tissue contain in their interior spiral fibres similar to those which have been described as present in certain forms of vascular tissue. In the anthers of the common furze the fibres are well marked (Fig. 116, Pl. 5); in the common hyacinth they are larger, and frequently present, in their intercellular spaces, bundles of raphides (Fig. 117, Pl. 57). In the white dead-nettle the fibre is irregularly deposited (Fig. 118, Pl. 5). In the anthers of the narcissus (Fig. 119, Pl. 5) the cells are almost vascular in their structure, and present the same appearance as those described under the head of annular ducts. (Compare Fig. 119, Pl. 5, with Fig. 44, Pl. 2.) In the crown imperial the fibres of the cells radiate from a central point in a stellate manner (Fig. 120, Pl. 5).

When the anther-cases have been examined, a little of the dust may be shaken on to a slide, and examined as an opaque or a transparent object. Each species of plant produces its own peculiar form of pollen. These little grains are truly cells. They are the cells of plants which in their position in the anther will not grow any further. They are destined to be carried into the pistil, where, meeting with other cells, they furnish a stimulus to their growth, and the embryo, or young plant, is produced. The history of the development of these cells, as well as of those in the interior of the pistil, is a very interesting one, and is one of those subjects of investigation which has been created by the aid of the Microscope. The pollen grains vary in size as well as form. They are frequently oval

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(Fig. 121, Pl. 5). In the hazel and many of the grasses they are triangular (Fig. 122, Pl. 5); in the heath they are trilobed (Fig. 123, Pl. 5); in the dandelion, and many of the compositous order of plants, they are beautifully sculptured (Fig. 124, Pl. 5). In the passion-flower three rings are observed upon them, as though they had been formed with a turner's lathe (Fig. 125, Pl. 5). In the common mallow they are covered all over with little sharp-pointed projections, like a hand-grenade (Fig. 126, Pl. 5). The microscopic observer should make himself acquainted with the forms of pollen grains, as, on account of their small size and lightness, they are blown about in all directions, and may be found on very different objects from those in which they have been produced. Some absurd mistakes have been committed by confounding pollen grains with other forms of organic matter.

The pistil, which is the central organ, seated in the midst of the stamens in the flower of plants, will afford a great variety of interesting points for examination with the Microscope. In the earliest stages of the growth of the pistil, thin sections of it may be made, and the position of the ovules observed. In the ovule will be found the embryo sac, a central cell, which, on being brought in contact with the pollen grain, grows into the seed. The seed contains the embryo, or young plant. In most plants this is sufficiently large to be seen by the naked eye; but it may, nevertheless, be examined with advantage by a low microscopic power. The seed is covered on the outside with a membrane, which is called the "testa." This membrane is often curiously marked, and the whole seed may be examined as an opaque object with the low powers of the Microscope. In order to do this, the light must be shut off from the mirror,

and, the object being placed on the stage, a pencil of light should be thrown upon it by the aid of the bull's-eye condenser. If a seed of the redpo ppy be now examined, it will be found to have a uniform shape, and to be reticulated on its surface (Fig. 127, Pl. 5). The seed of the black mustard exhibits a surface apparently covered with a delicate network (Fig. 128, Pl. 5). Some seeds have deep and curved furrows on their surfaces (Fig. 129, Pl. 5). The great snapdragon has a seed covered with irregular projecting ridges, having a granuled appearance (Fig. 130, Pl. 5). The seed of the chickweed presents a series of blunt projections (Fig. 131, Pl. 5). In the various forms of umbel-bearing plants, the seeds adhere to the fruit, and the fruit is commonly called the "seed." Such are caraway, coriander, dill, and anise seeds. The plants of this family are very common weeds in our gardens and fields, and may be easily procured for microscopic examination. Some of these fruits are covered over with little hooks (Fig. 132, Pl. 5), whilst others present variously-formed ridges and furrows, which are amongst the best means for distinguishing these plants the one from the other.

CHAPTER III.

A HALF-HOUR WITH THE MICROSCOPE IN THE COUNTRY.

A Compound Microscope is not easily conveyed and put up in the fields, but the produce of the roads and waysides may be easily brought to the Microscope at home. No one who has a Microscope should walk out into the country without supplying himself with a few small boxes, three or four small bottles, and a hand-net, in order to bring home objects for examination. The dry produce, which may be put into boxes, is of a different character from that which may be conveyed home in bottles. We shall, therefore, first direct attention to the minute forms of mosses, fungi, lichens, and ferns, which may be collected in boxes; premising, however, that many members of these families may be found without going into the country to seek for them.

Amongst the minuter plants and animals whose true nature can only be detected by the Microscope, many are composed of a single cell, whilst others, like higher plants and animals, are formed by the union of a large number of cells. The greater proportion of the one-celled, or unicellular plants, as they are called, are found in water; but some are found on moist rocks, stones, and old walls. Amongst these there is one of exceedingly simple structure, called gory dew (*Palmella cruenta*). This plant appears as a red stain upon the surface of damp objects. If a little of this red matter is scraped off the object to which it is

attached, and placed under the Microscope, it will be found to consist of a number of separate minute cells (Fig. 84, Pl. 4). This plant belongs to the same family as the red-snow plant, and there are a number of forms of these minute organisms, which, on account of their rapid growth and red colour, have given rise to alarming apprehensions, in former times, when their true nature was imperfectly understood. One of them attacks bread, and gives to it the appearance of having been dipped in blood. Of the same simple structure, but not having a red colour, is the yeast-plant, or fungus (Fig. 85, Pl. 4). This plant abounds in yeast, and may also be found in porter and ale. If vinegar is allowed to stand for some time, a minute plant is developed, called the vinegar-plant. In its earlier stages of growth it exhibits elongated cells, looking like broken pieces of thread (Fig. 86, Pl. 4). Threads more fully developed are often seen in decomposing fluids, and upon the surface of decomposing animal and vegetable substances (Fig. 87, Pl. 4). Such plant-like threads can be collected from the air in damp and unwholesome cellars and rooms, and were at one time supposed to be connected with the production of that fearful disease, the cholera. It has been rendered, however, exceedingly probable that all these appearances are but different forms of the fungus which produces common mould, and which is known by the name of *Penicillium glaucum* (Fig. 90, Pl. 4). This plant may be found on the surface of preserves and jellies, and consists of a mass of filaments or threads serving as its base, from the surface of which filaments rise up, bearing a number of minute cells which are the spores, or reproductive organs (Fig. 91, Pl. 4).

Plants such as these, and belonging to the family

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of fungi, are found everywhere on the leaves of plants in the summer and autumn, forming irregular spots, of a yellow, red, or black colour. If such leaves are brought home and placed under the Microscope, they present a never-failing source of interest. The red appearance on the leaves of wheat, called the rust, is due to one of these fungi (Fig. 88, Pl. 4). This appears to be an early stage of the fungus, which produces what is called mildew (Fig. 89, Pl. 4). These fungi are so common on the wheat-plant that their spores mingle with the seeds when ground into flour, and can be found. when carefully sought for, in almost every piece of bread that is examined under the Microscope. Mouldy grapes, pears, apples, and other fruits, present fungi, having the same general form as that of penicillium (Fig. 91, Pl. 4). Mouldy bread also presents a fungus of this kind (Fig 92, Pl. 4), but its spores are arranged in a globular form. A fungus not unlike the last has been described as growing in the human ear (Fig. 93, Pl. 4). The leaves of the common bramble present a fungus in which the spores are arranged on a more dense and elongated head (Fig. 94, Pl. 4). The *Oidium* which attends the blight of the vine (Fig. 95, Pl. 4), and the *Botrytis* which accompanies the potato disease (Fig. 96, Pl. 4), are other and interesting forms of these minute parasites. The common pea is subject to a blight which is accompanied by a peculiar fungus (Fig. 97, Pl. 4), which, when examined by a low power, presents a globular mass, surrounded by minute filaments. Under a high power the central ball is resolved into a series of little cases, containing in their interior the minute spores (Fig. 98, Pl. 4). Seeds, as well as fruits, are liable to the attacks of fungi during their decay. Fig. 99, Pl. 4, represents a fungus found in a mould

upon a common Spanish nut. This fungus looks like a red powder spread over the surface of the nut. A fungus has been described as attacking the oil-casks in the London docks: its fibres resemble threads of black silk (Fig. 100, Pl. 4). The spores are found scattered about the fibres. As we have already seen, fungi are found on the human body, and accompany certain forms of disease of the skin, more especially those of the head. In those cases the fungi insert themselves into the follicle of the hair, and introduce themselves into the structure of the hair, so that it either falls off or becomes disorganized (Fig. 101, Pl. 4). If the seed of wheat is allowed to germinate in a damp place, the little rootlet which it sends down will be found covered over with a minute fungus (Fig. 102, Pl. 4).

The microscopic structure of the higher forms of fungi is not without its interest. In the fungi a very elongated form of cellular tissue frequently occurs, and in the stem of the common mushroom it will be seen to be branched (Fig. 103, Pl. 4). The looser portions of the fibres of the mushroom, which are found in the earth at the bottom of the stem, afford even a better illustration of this structure (Fig. 104, Pl. 4). The gills of the mushroom, when put under the Microscope, display a number of small projections surmounted with four round cells (Fig. 105, Pl. 4); these are the spores arranged in fours, and which, on that account, are called *tetraspores.*

In the woods, in winter time, fungi abound, and their parts may be examined under the Microscope with great interest. Amongst the winter beauties of the forest, none are more attractive than the various forms of peziza, or cup-moulds. If a section be made through one of the cups of these beautiful fungi, they will present the appearance drawn in

Fig. 106, Pl. 4. A series of hollow elongated cases will be found lying between compressed elongated tissue. In these cases a series of rather oval minute cells will be found, which are the spores of the peziza. If these are magnified with a higher power, they will be seen to be covered over with minute spores.

Amongst the objects which more especially attract the attention of observers in the country, in winter time, are the various forms of lichens, which grow parasitic upon the barks of trees. There is one of a yellow colour, which spreads on palings and the barks of trees, like dried pieces of yellow paper. At the surface of the membranous scales of which the plant is composed will be found deeper yellow spots. If one of these is cut through, and a thin section placed under the Microscope, it will be found to possess very similar organs to the peziza. A series of cases will be found, containing the minute spores by means of which the plant is reproduced (Fig. 107, Pl. 4).

A walk across a damp uncultivated piece of ground will not fail to reveal some spots which are boggy. Amongst this the bog-moss must be looked for, and when found, it may be regarded as a good illustration of the family of mosses, and portions preserved for microscopic examination. The leaves afford interesting examples of fibro-cellular tissue (Fig. 108, Pl. 4), and this tissue may be examined from day to day, as affording an illustration of the process of development in vegetable tissue. Other forms of mosses may be found on banks, old walls, rocks, and crevices. The organs which produce the spores, or seeds, are well deserving the attention of the microscopic observer. These represent the pistils in the higher plants. The organs which represent the stamens are also very interesting, but they are not so easily procured.

We therefore proceed to describe the spore-bearing organ. This may be easily seen with the naked eye, although its beauties cannot be brought fully out without the aid of the Microscope. The part which contains the spores is seated on a little stalk, and is called the "urn" (Fig. 110*, Pl. 4). Covering the urn, and fitting on to it like a nightcap, is the calyptra (*a*). On slipping off the calyptra, a conical body fitting into the urn is observed, and this is called the "operculum" (*b*). If the operculum is now lifted off, there is revealed, below, a series of twisted hair-like threads (*c*), which are called the "peristome." These processes are held together by minute teeth (*d*). The spores (*e*) are found in the interior of the urn. All these parts are subject to great varieties in different kinds of mosses.

From the mosses we may pass on to the ferns. Like the mosses, they have no regular flowers, and the parts which correspond to the urns of the mosses are the small brown scaly-looking bodies seated on the back of the fronds, or leaves. In the male fern the little brown bodies which contain the spores are round (Fig. 111, Pl. 4), and in the common brakes they are placed on the edge of the fronds (Fig. 112, Pl. 4). These organs, which are called "sori," may be easily seen as opaque objects, under the lower powers of the Microscope. In the common hart's-tongue, or scolopendrum, the sori are arranged in elongated bands. In this case the sori are covered with a membrane called an "indusium." On opening this, the sori are found lying close together. Each one of these sori is found to be made up of a number of cases called capsules, or "thecæ," attached to a stalk by which they are fixed to the frond (Fig. 113, Pl. 4). These thecæ are beautiful objects under the Microscope. Springing from the top of the stalk is a series of cells which surround

the case, forming what is called the "annulus." This ring possesses an elastic power; so that when it breaks, the capsule is torn open, and the spores in the inside escape. The spores are covered over with little spines (Fig. 113, *a*, Pl. 4). The spores of ferns are often called seeds, but they are more like buds than seeds. If one of these spores is watched during its growth, it will be found that it grows into a little green membranous expansion, on the surface of which the two sets of organs resembling the pollen grains and ovules of the higher plants are developed. The representatives of the pollen grains are little moving bodies, resembling animalcules, which pass over the surface of the membranous expansion till they reach the ovules, or true spores of the fern, which they fertilize, and the young plant then shoots forth. The ferns, of which so many species may be found in a walk in the country, or cultivated in a Ward's case in town, are worthy the minute attention of the possessor of a Microscope, on account of the great variety of forms which their organs of fructification present.

The club-mosses are found on boggy moors and open places, and present a variety in the forms of their fructification. The reproductive organs are formed out of a transformed branch, and are found lying at the base of scale-like bodies, resembling the scales which form the fruit of firs and pine-trees (Fig. 115, *a*, Pl. 4). The spores of the club-mosses are of two kinds, large and small; hence they are called "megaspores" and "microspores." The last are very minute (Fig. 115, *b*, Pl. 4). When highly magnified, they present a reticulated appearance (*c*). In the interior of these spores is a minute vermicular body, which acts the part of the pollen in higher plants. The megaspores are much larger. They represent the spores of ferns, and produce an

expanded membrane, on which grow the true representatives of the ovules, which, coming in contact with the microscopic spores, develop new plants.

Another family of these flowerless plants, which have yielded highly interesting results to the microscopic observer, is the horsetail. If these are gathered in the spring of the year, they will present two forms; one showing the leaves and green parts of the fruit; the other, the leaves changed into reproductive organs. These may be very easily examined as opaque objects under the Microscope. The spores are seated on round shield-like disks (Fig. 114, *a*, Pl. 4). When the spores are examined by a higher power, they present four spiral filaments, which are twisted round the body of the spore (*b*). If the spore is breathed upon whilst under the Microscope, the spiral filaments gradually relax their grasp, and they become expanded and attached to the spore only at one end (Fig. 114, *c*, Pl. 4).

The study of the flowerless plants is one of never-ceasing interest. Within the last few years much has been done by the aid of the Microscope to clear away the mystery which surrounded the functions performed by certain organs they possess. Much more, however, remains to be done; and an interesting field is still open to the inquiries of the microscopist. We will now, however, take our Microscope to the pond-side, where we shall still find many plants to interest us, belonging to the lower, or flowerless groups, together with animals, the companions of their aquatic life, and the representatives of their simpler mode of existence.

CHAPTER IV.

A HALF-HOUR WITH THE MICROSCOPE IN FRESH WATER.

CISTERNS, ditches, ponds, and rivers, contain numerous objects to interest the microscopic observer. Some of these objects float on the surface of the water; others are found swimming about in the middle of the water; whilst the greater number, perhaps, are found at the bottom of the water. In collecting objects from fresh water, little bottles may be used, and a common spoon or small net employed for collecting them. Where the objects are only few, large quantities of the water should be allowed to stand, and the whole poured off, with the exception of a table-spoonful or two, which may be then placed in a wine-glass. A little of the sediment may be taken up in a pippet or glass tube, and conveyed to the animalcule-cage, and the cover having been put on, it may be placed under the Microscope. If the objects are moving about too rapidly, the cover may be pressed down till they are secured. They may be first sought out with a low power, and when it is wished to examine them more closely, a higher power may be put on.

Of all the forms of microscopic plants which are found in fresh water, those belonging to the families of desmids and diatoms are most interesting. We have already spoken of plants consisting of one cell, and these also consist of one cell; but they have this peculiarity, that their cells are divided into two equal parts, each part having the same

form as the other. The desmids are distinguished from the diatoms by their bright-green colour, and by their cells not depositing silex, or flinty matter, as is the case with the latter. The desmids sometimes abound in ditches and small pieces of standing water. Amongst other objects in a drop of water they are easily recognized by their beautiful bilateral forms and dark-green colour. One of the most charming of these is named *Euastrum* (Fig. 25, Pl. 2), and consists of two notched halves of a bright-green colour, with darker green spots. The green matter is composed of chlorophyle, the same matter that produces the green colour of leaves. Some of them assume a lunate form, and are named *Closterium* (Fig. 26, Pl. 2). There are various species of *Closterium*, all of the same general form, and occasionally occurring in very great abundance. Sometimes several of the cells are attached together, forming a long chain, as in the genus *Desmidium* (Fig. 27, Pl. 2), from which the family takes its name. These break up and go on growing. When they grow, the new cells are formed between the two halves of the parent cells (Figs. 134 and 135, Pl. 5). In a genus called *Scenedesmus*, several cells are united, and the two last halves are furnished with horns (Fig. 29, Pl. 2); at other times several cells unite, forming a globular mass, as in *Pediastrum* (Fig. 28, Pl. 2). In this case each cell presents two projections, forming objects of singular beauty.

The diatoms are more numerous and widely diffused than the desmids. The latter are decomposed, and their bodies perish when they die; but from the fact that the diatoms deposit silex in their structure, they are almost imperishable. They are found in great abundance in the mud of rivers, ponds, and lakes. They are also present in those

deposits of clay which once formed the bed of rivers and lakes, and which are now dry. In order to procure the diatoms from these deposits, the clay or earth should be well washed with pure water, and the deposit allowed to subside, and the water poured off. This may be repeated several times. The deposit is then to be washed with hydrochloric acid, and when the effervescence is over, the acid is poured off, and a fresh portion is added. This may be repeated several times, and when the hydrochloric acid ceases to act, nitric acid may be employed in the same manner. When no action occurs by its use cold, the deposit may be transferred to a watch-glass, and kept over a spirit-lamp, at a temperature of about 200°, for three or four hours. The deposit must then be well washed with pure water, to remove all the acid. The deposit will be found now to consist almost entirely of diatoms. If anything else be found, it will be grains of sand. By casting the deposit into a small quantity of water, and allowing the heaviest particles alone to subside, these will be generally found to contain the sand and larger diatoms. By repeating this process successively, the deposits consist gradually of smaller and smaller diatoms, which may be examined with gradually higher powers, in proportion to their minuteness. Some are perfectly round (Fig. 33, Pl. 2), and marked beautifully in the centre; others are triangular; some are square, and attached together (Fig. 32, Pl. 2, and Fig. 137, Pl. 5). The most common forms are those which are oval, or boat-shaped (Fig. 31, Pl. 2). These are again larger at one end than the other (Fig. 30, Pl. 2). The markings upon the surface are very various. In some forms the markings are exceedingly minute; so small are they, that certain species of diatoms have been used as

test-objects, for testing the highest powers of the Microscope.

Whilst living, the diatoms possess the power of moving about, and in some of them, as well as the desmids, a movement has been observed of the small particles in their interior. The diatoms are generally of a brownish or brownish-yellow colour, which seems to be due to a small quantity of iron in their composition. They are increased in the same way as the desmids, by the production of new cells between the parent frustules (Figs. 135, 136, Pl. 5).

Sometimes, attached to the bottom of a pond or river, or growing from immersed objects, or floating about in the water, will be found long green filaments. These are the fronds of confervæ. All forms of these—and they are very numerous—will be found most beautiful objects for examination. They may be laid on a slip of glass in water, and covered over with a piece of thin glass; or they may be placed in the animalcule-cage. They consist of a series of cells growing end to end, and their partition-walls can be easily seen. They are of a green colour, from the chlorophyle contained in their interior. In the case of the yoke-threads, the chlorophyle is frequently arranged in a spiral manner along the interior of the filament (Fig. 11, Pl. 1). These yoke-threads may be often seen to unite with each other, and the contents of one cell are emptied into the other; forming the spore of the plant (Fig. 133, Pl. 5). These spores, when they escape from the cell in which they are contained, move about with great rapidity. The moving power of the lower plants is well seen in the division of these confervæ, called *Oscillatorias* (Fig. 12, Pl. 1). As they lie upon the glass slide they will be seen to move over each other in all directions: hence their name.

Some of the spores formed by the confervæ move about by the agency of little organs called cilia. These are mere extensions of the motile matter of the cell, and are found very commonly in the animal kingdom. Occasionally, a number of these ciliated spores are aggregated together, forming a rapidly-moving sphere. Of this the *Pandorina morum* affords a good example (Fig. 13, Pl. 1), in which each spore possesses two cilia. But the most remarkable of this kind of moving plant is the *Volvox globator* (Fig. 14, Pl. 1). This beautiful moving plant was at one time thought to be an animalcule, but it is now regarded as a true plant. It consists of a large number of spores, or cells, each having two cilia, and connected together by a delicate network of threads. In the interior of this moving sphere are seen smaller globular masses, of a dark-green colour, which are the young of the volvox, which have not yet developed the network by means of which their spores are separated, and their ciliated ends presented to the water, and by means of which their movements are effected.

Another form which is now regarded as a locomotive plant is the *Euglena viridis* (Fig. 15, Pl. 1). It is often found in prodigious numbers, giving to water the appearance of green-pea soup. When placed under the Microscope, it frequently presents a red speck, or point, at one end, and an elongated tail at the other. The red spot has been regarded as an eye; but if it is watched, it will be found the red colour will often extend from the red spot to the rest of the body; and it is probable that the red colour is only a change in the condition of the chlorophyle contained in its interior. Amongst this class of plants it is not unfrequent for the chlorophyle to assume a red colour at certain stages of its growth.

The transition from the filamentous to the membranous form of these plants is well seen in the species of *Ulva*. These are found in both fresh and sea water. In the early stages of its growth, the ulva presents the filamentous form of a conferva (Fig. 24, *a*, Pl. 2). Gradually the cells of the filament split up into two or three seams (*b*); and this goes on till at last a broad flat membrane is produced (*c*).

If the plants of our fresh waters are interesting, not less so are the animalcules; for, just as we have one-celled plants so we have one-celled animals, and it was only by the aid of the Microscope that they were discovered and can be examined. Wherever the above plants are found, there will also be discovered animals to feed upon them. The animal is distinguished from the plant by its feeding on plants, whilst the latter feed on inorganic substances.

There is considerable difficulty in at once distinguishing between the lowest forms of animals and plants. Although the animal generally possesses a mouth, and a stomach in which to digest its vegetable food, there are some forms of animal life so simple as not to possess either of these organs. In the sediment from ponds and rivers there will frequently be found small irregular masses of living, moving matter. If these are watched, they will be found to move about and change their form constantly. As they press themselves slowly along, small portions of vegetable matter, or occasionally a diatom, mix, apparently, with their substance. Cells are produced in their interior, which bud off from the parent, and lead the same life. These creatures are called amœbas (Fig. 16, Pl. 1); and though they have no mouth or stomach, they are referred to the animal

kingdom. They appear to be masses of protein (*sarcode*) without any cell-wall. If we suppose an amœba to assume the form of a disk, and to send forth tentacles, or minute elongated processes from all sides, we should have the sun animalcule (*Actinophrys Sol*), (Fig. 17, Pl. 1). This curious creature has the power, apparently, of suddenly contracting its tentacles, and leaping about in the water. It can also contract its tentacles over particles of starch and animalcules, and press them into the fleshy substance in its centre. This is undoubtedly an animal, but it has no mouth or stomach. A large number of such forms present themselves under the Microscope. Some of them are covered with an external envelope, which they make artificially, by attaching small stones and other substances to their external surface, as in the case of the *Difflugia* (Fig. 18, Pl. 1); or they may form a regular case, or carapace, of cellulose, as is seen in *Arcella* (Fig. 19, Pl. 1). We shall meet again with forms resembling these when we take our Microscope to the sea-side.

One of the most common animalcules met with in fresh water, and whose presence can easily be insured by steeping a few stalks of hay in a glass of water, is the bell-shaped animalcule. These animalcules, which are called *Vorticella*, are of various sizes. Some are so large that their presence can easily be detected by the naked eye, whilst others require the highest powers of the Microscope. They are all distinguished by having a little cup-shaped body, which is placed upon a long stalk (Fig. 35, Pl. 2). The stalk has the peculiar power of contracting in a spiral manner, which the creature does when anything disturbs it in the slightest manner. In some species these stalks are branched, so that hundreds of these creatures are

found on a single stem, forming an exceedingly beautiful object with the Microscope. The stalks of these compound vorticellæ are contracted together, so that a large mass, expanding over the whole field of the Microscope, suddenly disappears, and, " like the baseless fabric of a vision, leaves not a wreck behind." A little patience, however, and the fearful creatures will once more be seen to expand themselves in all their beauty. The mouth of their little cup is surrounded by cilia, which are in constant movement ; and when examined minutely, they will be found to possess two apertures, through one of which currents of water pass into the body, and from the other pass out. Not unfrequently the cup breaks off its stalk. It then contracts its mouth, and proceeds to roll about free in the water. Many other curious changes in form and condition have been observed in these wonderful bell-shaped animalcules.

If, now, we go to a very dirty pond indeed, into which cesspools are emptied, and dead dogs and cats are thrown, we shall find abundant employment for our Microscope in the beautiful forms of animalcules which are placed by the Creator in these positions to clear away the dirt and filth, and prevent its destroying the life of higher animals. In such waters, amongst a host of minor forms, we are almost sure to meet with the magnificent *Paramœcium Amelia* (Fig. 34, Pl. 2). He moves about the water a king amongst the smaller prey on whom he feeds without ceasing. He is of an oblong form, covered all over with cilia, and very rapid and active in his movements, as able to dart forwards as backwards, and turning round with the greatest facility. In his inside several spots are observed. If a little indigo or carmine is introduced into the water in which he lives, these spots

become coloured by his taking up these substances. From this, Ehrenberg concluded that these spots were stomachs, and as such spots are very common amongst these animalcules, he called them many-stomached (*Polygastrica*). There is, however, reason to doubt the correctness of this conclusion of the great microscopist, as, although these spots exist in the body, they are not necessarily stomachs. They are, in fact, empty spaces, or vacuoles in the interior of the little lump of sarcode of which the animal is composed. They are found in the vorticella, and in most of the animalcules.

All animalcules have been called infusory, because they seem so abundant in all kinds of vegetable infusions. Ehrenberg divided them into *Polygastric* and *Rotiferous*. The last are also called wheel-animalcules, as, when looked at through the Microscope, they appear to be supplied with little wheels on the upper part of their body. The most common form of these creatures is the *Rotifer vulgaris* (Fig. 36, Pl. 2). The branches or leaves of any of our common water-plants can scarcely be examined without some of those pretty little creatures being found nestling upon them. The structure of this creature is highly complicated, and the family to which it belongs is far removed from the polygastric animalcules with which it is often associated. On examination, the wheels will be found to consist of two extended lobes, the edges of which are covered with cilia. These cilia are in a constant state of movement, and produce the appearance of wheels moving on an axis. Between the wheels is the entrance to the mouth, which, in many species of wheel-animalcules, is furnished with a strong pair of jaws. This leads to an œsophagus, a stomach, and an intestinal tube. Two little spots on the neck seem to indicate the existence of eyes;

whilst a projecting organ, whose function is imperfectly understood, is seen directly below them. The tail is finished off with a pair of little nippers, by which the creature has the power of attaching itself to objects. When moving, its whole body is extended, but it has the power of drawing itself up like a telescope in its case, and appearing almost round.

The wheel-animalcules abound in our ponds and rivers, and sometimes occur in great numbers in the aquarium. They are very various in their forms, and some of them possess great beauty. Some of them are fixed, forming a little case or tube on the outside of their bodies, in which they dwell.

CHAPTER V.

A HALF-HOUR WITH THE MICROSCOPE AT THE SEA-SIDE.

On a visit to the sea-side, the Microscope is an essential instrument to all who would wish to study the wonders of the ocean. It is a curious fact, that the few grains of common salt in the gallon of sea-water seem to determine the existence of thousands of plants and animals. We shall therefore find living in the sea-water, plants and animals belonging to the same families as those in fresh water, but belonging to entirely different species.

The sea-weeds present strikingly different forms. Although many of them are microscopic, and belong to the families of *Diatomaceæ* and *Confervaceæ*, all the larger forms present interesting objects for examination in the structure of their fruit-bearing organs. No better subject for the latter purpose can be procured than the common bladder-wrack, which is so abundant on all our shores. If a frond of this fucus is examined, there will be found at certain parts a swollen mass, dotted over with round yellowish bodies. If one of these is taken and carefully pressed between two pieces of glass, it will present the spores surrounded with hairs of the most delicate and various structure. The spores are divided into four parts, and on this account are called tetraspores (Fig. 109, *d*, Pl. 4). The bladder-wrack is frequently covered with minute parasites; one of the most common of these is *Polysiphonia fastigiata* (Fig. 109, Pl. 4).

This little plant is branched, and the stems present a series of flattened cells. On the branches are placed the fruit-bearing organs, in the form of little capsules (*a*). These capsules contain the tetraspores (*b*). At the ends of the branches are organs of another kind, representing the stamens, and which are called *antheridia* (*e*). The sea-weeds present a great variety in the form of these organs, and may be easily preserved for investigation in small glasses of sea-water.

The animal structures of the sea-water must now, however, claim our attention. Amongst the lowest forms of animal life are the sponges. They are frequently cast on the shore with sea-weeds, and afford interesting objects for the Microscope. They are composed of animal matter, which lies upon a structure of horny, calcareous, or siliceous matter. The common sponge which is used for domestic purposes may be taken as a type of the whole group. If a thin section of the common sponge is made with a pair of sharp scissors and placed under a low power, it will be seen to be composed of a network of horny matter (Fig. 138, Pl. 5). If, now, we take any of the common forms from our own sea-shore, we shall find that the network is composed of siliceous spicules lying one over the other (Fig. 139, Pl. 5). If one of these spicules is examined (*a*) and compared with a spicule from another sponge, it will be found to differ in form and size; and the species of sponges can actually be made out by the shape of their spicules. There is a little boring sponge, called *Cliona*, found in the shells of old oysters, which has its spicules pin-shaped (Fig. 140, Pl. 5). The fresh-water sponge has very peculiar-shaped spicula (Fig. 141, Pl. 5). In some, the siliceous bodies are round, with projections, as in

Tethea (Fig. 142, Pl. 5). Sometimes the spicula assume a stellate form, and are even branched (Fig. 143, Pl. 5).

Amongst the lowest forms of animal life, none are more interesting to the microscopic observer than those belonging to the family of *Foraminifera.* They are thus called on account of the minute holes which cover their shells. If we suppose a creature as simple in structure as the amœba or sun animalcule (Figs. 16 and 17, Pl. 1), with the power of forming a little calcareous shell, we should have a foraminifer. Some of these shells have the form of a nautilus, and when first observed they were supposed to belong to this group of shell-fishes. In form they certainly resemble the higher foems of mollusca (Figs. 20 and 22, Pl. 1). Sometimes, however, they are elongated or cone-shaped (Fig. 21, Pl. 1). They may often be found alive at the sea-side, nestling in the roots of the gigantic laminarias which are so often thrown on the shore after a storm. If the roots of these plants are washed, and the deposit examined carefully, the foraminifera may often be found alive. When this is the case, they will be found to have the power of protruding through the little holes in their shells their soft bodies, in the form of long tentacles (Fig. 23, Pl. 1). With these they seem to have the power of moving as well as of taking up the matters by which they are nourished. The shells of these creatures are not so small but they may be seen with the naked eye, and they need only a low power to observe all their structure. They are found at great depths in the ocean, and have been brought up by the dredge from the deepest parts of the Atlantic. They are very abundant in some rocks, especially in the chalk: they may be obtained from the latter substance by rubbing a piece of chalk with a brush

in water. The water must be first decanted from the coarser particles of chalk, and in subsequent deposits the foraminifera will be found. They may be obtained from dry sand in which they are contained, by throwing the sand into water, when the sand will sink and the foraminifera will swim on the surface, and may be skimmed off. They are best examined as opaque objects.

The family of polyps will next command attention. One of the most simple forms of this family is found in ponds and rivers, and is called the fresh-water polyp or hydra (Fig. 144, Pl. 5). It may be easily observed adhering to plants with the naked eye, and needs only a low power with transmitted light, to observe it accurately. Its body is cup-shaped, surmounted with eight long tentacles, which it has the power of retracting. It produces young ones by the process of budding, and the buds may be often seen protruding from the side of their parents. It is very tenacious of life, and may be cut into several pieces, and each part will grow into a new hydra. These, with many other polyps and the jelly-fish, have their flesh filled with little hair-like bodies, which, from their property of stinging in some species, have been called stinging-hairs (*a*). If we suppose several of these hydras placed in little cups upon a common branch or stem, we shall have a *Sertularia* (Fig. 145, Pl. 5). These polyps are very common on all our sea-shores; and the branches and cups are often cast up on the shore, and regarded by the uninstructed as sea-weeds. Such polyps assume a variety of forms. When the cups are fixed on hinged stalks, they constitute the genus *Campanularia* (Fig. 146, Pl. 5). These cups are often objects of great beauty, as in those of *Campanularia volubilis* (Fig. 147, Pl. 5). The branches or skeletons on which these polyps

are situated, are called *polypidoms*. It is the polypidom which constitutes the coral in the family of polyps, producing the masses of carbonate of lime which sometimes cover the bottom of the ocean and form reefs in the sea. In one family of polyps, known as sea-fans (*Gorgonia*), the calcareous polypidoms contain spicula of various forms, which are beautiful objects under the Microscope (Fig. 148, Pl. 5).

Another family of animals common enough in the sea, are the star-fishes and sea-eggs. Although not themselves microscopic, certain parts of their structure present very interesting objects for examination. If a section is made of one of the spines of the common echinus, or sea-egg, it presents under a low power a beautifully radiated structure (Fig. 149, Pl. 5). The suckers, also, of the same animal present little rosettes (Fig. 150, Pl. 5). Upon the surfaces of both star-fishes and sea-eggs will be found little movable bodies which are called *pedicellariæ*. In the sea-egg they possess three movable nipper-like limbs (Fig. 151, Pl. 5), whilst in the common star-fish they present only two (Fig. 152, Pl. 5). A controversy has been raised on the question as to whether these bodies are parasitic animals, or part and parcel of the structure of the creature on which they are found. As they are so constantly present, they are probably parts of the animal on which they are found. The movements of these nippers are very active, and they frequently lay hold of objects which pass near them.

As common on the shore as the polypidoms of the polyps, are the animal skeletons called sea-mats. When placed under a low power, and viewed by reflected light, the sea-mat is composed of little cavities or cells (Fig. 153, Pl. 6).

In each one of these is seated a creature of much more complicated organization than the polyps just examined. It has, it is true, a ring of tentacles ; but if these are examined, the tentacles are found to be covered with cilia (Fig. 159, *a*, Pl. 6). This family of creatures are called *Polyzoa*, and form a group of animals which are classed with the *Mollusca*, or shell-fish. Sometimes these creatures attach themselves to sea-weeds, oysters, stones, and other objects at the bottom of the sea, forming a kind of cellular membranous expansion. Such are the species of *Lepralia* (Fig. 153, Pl. 6). Sometimes the cells are elongated and elevated above the surface of the object on which they are placed, as in the case of *Bowerbankia* (Fig. 154, Pl. 6). A beautiful form of these creatures is the shepherd's-purse coral (Fig. 155, Pl. 6). This creature belongs to a group of the polyzoa, remarkable for possessing little processes on the margins of their cells, in shape resembling the bowl of a tobacco-pipe. On examining them with the Microscope, they present a very complicated organization : they possess two jaw-like processes, which open and shut like a bird's bill, and from this fact they have been called *avicularia*, or bird's-head processes (*a*). In other species, as in *Bugula avicularia* (Fig. 156, Pl. 6), these creatures possess not only the bird's-head process, but a second, consisting of a long bristle or seta, attached by a joint to a process below (*b*). These bodies are called *vibracula*, and the bristle-like extremity is kept constantly in action. Few objects are more curious under the Microscope than these avicularia and vibracula in a state of action. Whilst the function of the vibracula (*a*) seems to be to sweep away objects that would interfere with the life of the animal in the cell, it has been suggested that the avi-

cularia secure by their jaws the food necessary for its sustenance. Of the various forms which the cup itself assumes, none are more interesting than those of the snake-head zoophyte (Fig. 157, Pl. 6), in which it assumes the form of a snake's head, with the tentacula projecting like a many-parted tongue. The polyzoa are also inhabitants of the fresh water. Of these the most common form is *Plumatella repens* (Fig. 159, Pl. 6). The eggs of a fresh-water species, *Cristatella mucedo*, are covered with projecting spines with double hooks at their extremities, perhaps for the purpose of catching hold of objects (Fig. 160, Pl. 6). Such eggs may be often found upon portions of water-lily, bulrush, and other aquatic plants which float about in our rivers, lakes, and ponds.

Although but few of the shell-fish belonging to the large class of mollusca are microscopic, yet the structure of their shells can only be investigated by the aid of the Microscope.

If any common shell be picked up on the sea-shore, it will be found to possess a rough outside, generally of a darker colour, and sometimes beautifully ornamented, whilst on the inside it is smooth and frequently of a rose-colour. This inner smooth layer is called the *nacre* of the shell; and it is from this substance that pearls are formed in the interior of many shells. Both the outer and the inner layers present different kinds of structure in different species of shells. The outer layer can be well examined in the shell of the mollusc called the pinna. The outer layer in this shell projects beyond the inner, and may be easily submitted to examination by reflected light under a low power (Fig. 161, Pl. 6). The external surface presents the appearance of hexagonal cellular tissue. If a portion of the shell is ground down, so as to

form a very thin layer, it may be examined with transmitted light, and its hexagonal structure will be much more apparent. If a portion be examined lengthwise, it will be seen that the hexagons result from the shell being composed of a series of hexagonal prisms (Fig. 162, Pl. 6).

All bivalve shells partake, more or less, of this character; and if a portion of the outer coating of the shell of the oyster be examined, it will be found to present a general resemblance to that of the shell of the pinna (Fig. 163, Pl. 6). In many shells the inner layer is almost structureless, but in those cases where the smooth white appearance is presented which is called *mother-of-pearl*, it consists of a series of waved laminæ lying irregularly one on the top of the other (Fig. 165, Pl. 6). In other shells this membranous internal layer is traversed by tubes, as is seen in the genus *Anomia* (Fig. 164, Pl. 6).

The shells of the crustacea also present a series of very interesting structural differences. The shell of the common prawn, when a thin section is made, presents a series of bodies looking like nucleated cells (Fig. 166, Pl. 6). Many shells present this appearance, and it was at one time supposed to indicate clearly that the shell originates in cell-growth as well as other parts of the structure of an animal. It has been, however, recently shown, that such appearances as that presented by the prawn-shell may be produced by the crystallization of inorganic salts in contact with organic substances in solution, independent of a living organism.

Surprising as it may seem to some persons, the teeth of mollusca afford beautiful objects for microscopic examination. All that is necessary to examine these organs is, to take the palate, or

tongue as it is called, of any of our common molluscs, and to stretch it on a glass slide, when it may be seen by transmitted or reflected light. In the common whelk, the teeth are placed in rows, and are composed of a broad base with four projecting points, the two outer of which are larger than the inner (Fig. 167, Pl. 6). In the limpet, the teeth present four projections, which are all of the same size (Fig. 168, Pl. 6). In the common periwinkle another kind of arrangement is observed (Fig. 169, Pl. 6).

When sea-side specimens have been observed and put up, the fresh-water mollusca may be next investigated. Here other forms will be observed. The species of the genus *Limneus* are found in every pond, and kept in every aquarium. The tongues of these creatures (Fig. 170, Pl. 6) will give a lively idea of the nature of the scavenging processes they carry on.

The scales of fishes are interesting microscopic objects. The structure of these organs indicates the family of fishes to which they belong. It is in this way that a single scale found in a rock will throw a light on the nature of the fishes which inhabited the seas or rivers from which the rock was deposited.

Fishes' scales have been called *ganoid*, *placoid*, *cycloid*, and *ctenoid*, according to the families to which they belong. The sturgeon has *ganoid* scales. They are shiny, and have a structure like bone (Fig. 171, Pl. 6).

The sharks, rays, and skates have *placoid* scales. They are frequently terminated with a prickle, as in the scales of the skate (Fig. 172, Pl. 6). This structure resembles the tubular structure in the teeth of the higher animals.

Fish-scales are frequently permeated with little

tubes (Fig. 173, Pl. 6). These appear to be the work of some minute parasite which has hitherto evaded the scrutinizing investigation of the microscopic observer.

The fishes of the earlier rocks belong to the *ganoid* and *placoid* groups. The great majority of recent fishes belong to the remaining groups. The common sole affords an instance of the *ctenoid*, or comb-like scale (Fig. 174, Pl. 6).

The *cycloid*, or circular scales, are found in such fish as the whiting (Fig. 175, Pl. 6). It is not uncommon to find in these scales calcareous particles (*a*). In the sprat the *cycloid* scale assumes a form almost as broad as it is long (Fig. 176, Pl. 6).

The examination of these hard structures in the marine creatures is a good preparation for the further study of those hard parts in the higher animals to which the name of bone and ivory is given. Such things may, however, be procured in the house; and when the rain is falling, and the sea-side forsaken, and the country miserable-looking, we can still enjoy the long winter evenings with our Microscope in the house.

CHAPTER VI.

A HALF-HOUR WITH THE MICROSCOPE IN-DOORS.

For amusement and instruction with the Microscope, we need scarcely stir out of our rooms. The very hairs on our head may be made objects of interesting investigation, and especially if we compare them with the hairs of other animals, and the appendages generally of the skin. The fine outer coating of the skin is composed of minute scales, which are flattened cells, and may be easily observed by scraping a portion of the skin on to a glass slide with a drop of water on it. The nails, the hairs, and other appendages of the skin, are composed of the same kind of scales, or cells. These cells are developed in little pits, or follicles, from which the hair is projected, as it were, by their growth from below. Under a low power the cells of the human hair cannot be observed. It presents, however, a well-marked distinction between the outside, or *cortical layer*, and the interior, or *pulp*. The latter, by a high power, especially if the hair has been first submitted to the action of sulphuric acid, will be found to contain cells more or less spherical, whilst the former contains cells more or less flattened. These project a little beyond the edge of the hair, so that its sides are not quite smooth (Fig. 179, Pl. 7). By placing a hair between two pieces of cork, fine transverse sections of it may be made by means of a sharp razor, when the pulpy portion will present a dark

appearance in the centre (*a*). The hairs of animals offer a great variety in the disposition of the cells of which they are composed. The hairs of the mouse present a series of dark partitions running across the hair between the cells. In the younger hairs, these partitions are single (Fig. 180, *a*, Pl. 7), but in the older ones they appear double (*b*). The hairs from the ear of the mouse present these dark partitions very distinctly (*d*). Such hairs stand intermediate between true hair (*e*) and wool. A piece of flannel or blanket will afford a good illustration of the latter (Fig. 225, Pl. 8). In this case it will be seen that the scales, or cells, of the cortical part, project beyond the surface, and render the wool rough. This roughness of the outside renders it possible for such hairs to be used in the process of felting; the rough sides of the hairs adhering together. Human, and other smooth hairs, will not felt.

The fibres of plants used in weaving may be conveniently compared with hairs derived from the animal kingdom. The woody fibre of the flax may be obtained from a linen handkerchief (Fig. 224, *b*, Pl. 8). The apparent knots in the fibre arise from injury in the uses to which the fabric has been applied. The original fibres have no such fractures (*a*), and are perfectly smooth. So are the fibres of silk (Fig. 226, Pl. 8). Cotton-wool is produced from the inner surface of the pod, or fruit, of the cotton-plant (Fig. 227, Pl. 8). It becomes twisted during its growth, and although not so strong as linen or silk, its irregular surfaces permit its being spun into a strong yarn, from which all cotton fabrics are made. The young microscopist should make himself acquainted with the forms of these various fibres; as, from their being so constantly present in rooms where the Microscope is used, and

occasionally used in cleaning the apparatus, they often present themselves as foreign substances.

The hair of the bat (Fig. 181, Pl. 7) presents a singular instance of the projection of the scales, or cells, in a regular form. Hairs are not often perfectly round;—in the peccary they are oval (Fig. 182, Pl. 7); and if a transverse section of this hair is examined, it will be found that the cortical substance projects completely into the pulpy part of the hair in several places, so as to break up the pulp into several separate sections.

In some cases it is not easy to distinguish between outside and inside structure, as is seen in the hair of the musk-deer (Fig. 183), in which the whole is found to consist of a mass of hexagonal cellular tissue, similar to that seen in the pith of plants.

Insects are frequently covered with hairs, especially in their larva, or caterpillar state. These hairs, when stiff and sharp, penetrate the skin, and produce irritation there. This is the case with the large tiger caterpillar. The hairs of this caterpillar are furnished with a series of barbs, which, when they once penetrate the skin, are not easily removed (Fig. 184, Pl. 7).

Spiders are frequently covered with hairs, some of which are branched (Fig. 185, *a*), others present a spiral appearance (*b*), whilst, again, others offer a series of small bristle-like hairs running down each side of the primitive hair (*c*).

Many of the crustacea have hairs upon their shells. Those upon the flabellum of the common crab have minute bristles on one side of the parent stalk (Fig. 186, Pl. 7), so as to form a little comb, with which to brush off the impurities from its branchiæ. A live crab from the aquarium may be watched for the purpose of observing these cleanly movements.

The study of the uses of the epidermal appendages is one full of interest, as in no one set of structures do we find a greater variety of adaptations of a common plan to the wants of the creatures in which they are found. The feathers of birds belong to the same type of structure as the hairs of animals. If the pinnæ of a common goose-quill, used for a pen, are examined, the pinnules will be found to be covered with minute hooks (Fig. 187, Pl. 7). These hooks on the upper surface are so arranged that they catch the nearly plain and slightly toothed pinnules on the lower side.

The down from the feathers of the swan, with which pillows and beds are stuffed, is also a beautiful object, and its microscopic structure (Fig. 188, Pl. 7) will at once reveal the cause of its lightness, softness, and warmth.

Amongst the creatures which domesticate with us are certain insects which are more frequently discovered than acknowledged. However disagreeable their presence may be, they become interesting objects for microscopic investigation, and are not less calculated to excite our admiration than creatures more ceremoniously treated. We first call attention to the flea. This beautiful insect belongs to a large family, each species of which has its peculiar habitat in the epidermal appendages of some of the higher animals. The head of the human flea may be taken as the type of the family (Fig. 189, Pl. 7). It is furnished with antennæ, mandibles, and a pair of lancet-shaped jaws, with which it makes little wounds in the skin, and into which it pours the irritating secretion which renders its bite a source of annoyance. Its eye, large hind legs, and ornamental saddle on its back, are all deserving of attention.

Let us now seek another too common inhabitant of London houses, the bed-bug, and, having decapitated him, submit his head to a low power. He, too, is a biting creature ; and you will observe that his jaws are finer than those of the flea, and are like a pair of excessively fine sharp hairs (Fig. 190, Pl. 7) ; they are inclosed in a sheath, from whence they are projected when used. In the same sheath is the tongue, which performs the double office of sucking up the blood of its victim and depositing in the wound an acrid and irritating secretion. The antenna and eyes of the bug are also worthy of examination. From the latter will be found projecting minute hairs.

A still more despised animal may now be sought. It also belongs to a large family, and each mammal and bird seems to be attended with its peculiar louse. Two species are found in dirty and diseased conditions of the human body. Disgusting as connected with want of cleanliness, they are, nevertheless, perfectly harmless. The head and mouth (Fig. 191, Pl. 7) indicate that these creatures are adapted to live on the secretions of the skin. The above animals all belong to the much larger group of creatures adapted to live as parasites upon other animals.

The head of the common gnat may be now examined for the sake of comparison (Fig. 192, Pl. 7). In this creature, the eye of the insect may be studied. It is what is called a *compound* eye, and is composed of innumerable small lenses ; each one of which is connected with a twig of the optic nerve, and capable of receiving impression from external objects. The little lenses terminate on the convex surface of the eye, presenting an immense number of hexagonal facets (Fig. 203, Pl. 7). In the common house-fly, there are said to be

4,000 of these facets; and in the cabbage-butterfly 17,000. The antennæ of the gnat are very beautiful; and, in fact, these organs in insects afford an endless variety of forms. At their base, in the gnat, is seen a round process on which they are seated, and it has been supposed that they are organs of hearing. Whether they are organs of hearing or not, it is very certain that they are organs of touch, and the creature is very susceptible of the slightest stimulus applied to them.

The head of the honey-bee may be now examined; and if a careful dissection is made of its mouth, a marvellous apparatus is unfolded to view (Fig. 194, Pl. 7). At the base is seated the so-called *mentum*, and on each side are placed the *mandibles;* above these, and longer, are the *maxillæ*, and on each side of the prolonged central organ, called the tongue, are placed the labial palpi. The tongue can be retracted between the palpi as into a sheath. It is marked by a series of annular divisions, and, by a high power, will be seen to be covered over with hairs. This is the organ by means of which the bee "gathers honey all the day."

Whilst examining the bee, its sting may be taken out and placed under a low power, when it will be found to present the appearance of a pair of spears set with recurved barbs, which run halfway down one side of each half of the sting (Fig. 193, Pl. 7). Between these two darts is placed a canal, down which are poured the contents of the poison-bag, producing the painful effects of wounds from these instruments.

To return to the head and mouth of insects:—The tongue of the bee may now be compared with the same organ in the butterflies, which, in them, assumes the form of a proboscis, and is called an *haustellum* (Fig. 195, Pl. 7). This instrument is

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coiled up when the insect is at rest, and is the organ by means of which the creature sucks up its nutriment from the flower. It has a series of lines running across it.

If the head of the common blow-fly be now examined, it will be seen that the tongue, instead of being elongated as in the latter instances, is expanded laterally (Fig. 196, Pl. 7). This is a very beautiful object, and when viewed by transmitted light, a series of spiral bands are observed to wind across each half of the tongue.

The head of the spider presents an interesting development of the mandibles. These organs are in pairs, each mandible consists of two joints: one is small, sharp, and hooked; whilst the other is large and short, and contains within it a bag, or poison-gland (Fig. 197, Pl. 7), so that when the creature seizes its prey, the bag is pressed on, and a drop of the poison exudes. This structure is similar to what is met with in the poisonous serpents, where a poison bag is seated at the base of a tubular tooth.

The head of the spider affords also a good example of what are called *simple* eyes. Besides the compound ones before mentioned, insects have also these simple eyes (Fig. 201, Pl. 7). They consist of a single lens (*a*), and are placed in various positions in the heads of spiders.

The skin of the common garden spider is covered with hairs. These appear to surmount a series of concentric plates (Fig. 202, Pl. 7). They vary in form in different species of spider; and the skin of all should be examined for the purpose of observing these differences. The web of the spider should also be examined. The cords of these beautiful structures which run from the centre to the circumference of the web, are plain (Fig. 207, Pl. 7); whilst those

which form the concentric lines are beaded with drops of a glutinous substanee. It is by means of this adhesive matter that the webs are held together. Nor should the microseopist neglect examining the spinnarets of the spider, by which these beautiful threads are elaborated.

The breathing organs of insects are well deserving attention. Their bodies are perforated at the sides, and the openings thus formed, called *spiracles*, lead into tubes which are branched, and are called *trachea.* These air-tubes are composed of a delicate membrane, which is supported on a series of delicate rings, which are easily traced into the more minute branches (Fig. 212, Pl. 8). The spiracle is not an open hole. In the common house-fly (Fig. 205, Pl. 7), and the water-beetle (*Dyticus*) (Fig. 206, Pl. 7), it is covered over with irregular branched processes from the sides of the opening. The objeet of this obstruction is probably to prevent particles of dust, and other foreign substances, from entering the air-passages, and thus ehoking the animal.

The legs of insects will afford an almost unlimited supply of objects for examination. The spoilt speeimens of a summer's capture may well supply materials for a winter's examination. The legs of insects are composed generally of five parts, jointed together. The lowest of these is called the *tarsus*, or foot. It is variously formed to adapt it to the locomotive habits of the inseet. In the common fly it is terminated with a pair of disks, which are covered with suckers, called *pulvilli* (Fig. 198, Pl. 7). By means of these suckers the animal is enabled to lay hold of smooth surfaces, and thus to crawl up them. They also exude a glutinous matter, which assists in this process. The same kind of arrangement is observed in the

common bee (Fig. 199, Pl. 7). The feet are also covered with hairs, and are frequently supplied with hooked joints, which assist the animals in laying hold of rough objects where their suckers would be of no use. In the spider there are no suckers, but the hooked joints and hairs enable the creature to crawl with facility (Fig. 200, Pl. 7). In the *Dyticus*, the fore leg is supplied with two large suckers (Fig. 209, *a*, Pl. 8), besides a number of smaller ones, and a hook; whilst the foot of the middle leg is destitute of the large suckers (*b*).

The legs of beetles are often covered with little cushion-like bodies, which undoubtedly act as suckers (Fig. 214, Pl. 8). The three legs often differ very much from each other, and probably perform modified functions according to their structure. This is well seen in the legs of the whirligig-beetle (*Gyrinus natator*) (Fig. 208, Pl. 8), in which the first leg (*a*) is very much elongated, whilst the third is broad and short (*c*), and adapted for swimming, from its oar-like form. The second leg (*b*) is intermediate in form and size.

As a contrast to these legs, adapted for the varied functions of the perfect insect, the leg of any common caterpillar may be examined (Fig. 213, Pl. 8); when it will be found to consist, at its extremity, of a little sac surmounted with hooks.

The wings of insects, too, are beautiful objects; easily investigated by a low power. The nerves which run through them are supplied with trachea, and they thus become organs of respiration. The under wing of the bee is supplied with a series of hooks (Fig. 204, Pl. 7), which slide on a thickened nerve on the upper wing (*a*), and keep the wings steady during flight.

The *lepidopterous* insects, including the butterflies and moths, have got their name from the scales on

their wings. These scales assume a wonderful variety of form, and claim a large amount of attention from the microscopic observer, and cannot be neglected by the entomologist.

The little blue argus butterfly has scales in the shape of a battledore (Fig. 215, Pl. 8); the handle being the part attached to the wing. All the scales have handles of this sort, whatever be their shape (Fig. 216). Sometimes the scale is broad at the base, and pointed at top. In the meadow brown butterfly, the point is surmounted with little clubbed projections (Fig. 217, Pl. 8). Scales are found on other insects besides moths and butterflies: thus they are found on the common gnat (Fig. 218). Besides their curious forms, the scales are marked with lines which are exceedingly delicate, and require the highest powers of the Microscope to bring them out. Some of the scales are thus used as tests for the powers of the Microscope.

Just as we have seen in the tongues and legs of insects, the same parts expanded or compressed according to the wants of the animal, so we find the scales assuming various forms. The scales stand in exactly the same relation to the hairs in insects, that the scales of fishes and reptiles do to the feathers of birds and the hairs of mammals. Hair-like scales are therefore not uncommon (Figs. 219, 220, Pl. 8). Such may be found on the common clothes-moth.

The young microscopist for whom our book is written, and with which we hope to make him dissatisfied, in order to facilitate his progress in natural history inquiries, will not spend much time in making dissections. Should he wish to do so, he will find the structure of insects full of interest. He has only to open a cockroach to see how curiously their digestive apparatus is con-

structed. This insect has a gizzard, and at the upper part it is beset with six conical teeth (Fig. 210, *a*, Pl. 8), which, working together, reduce its food to a pultaceous mass previous to digestion. When cut open, the position and relations of these teeth (*b*) can be easily seen. The gizzard of the cricket is also supplied with teeth (Fig. 211, *a*, Pl. 8): it has three longitudinal series of teeth, and each row in each series contains seven teeth (*b*). The family of insects to which the cricket belongs (*Orthoptera*), afford several other instances of the same kind of structure in the gizzard. It will be interesting to compare these teeth of the insects with those of the mollusca and the wheel animalcules.

We must satisfy ourselves with having shown the student the way to cultivate a large field of interesting and instructive phenomena in the insect world, without going further into detail.

The tissues or textures of which animals are built up or made of, may be easily procured in-doors. We have spoken of the hard parts which form the outer skeleton of the lower animals, as the molluscs, crabs, and fishes; the internal skeleton of the higher animals affords a not less interesting field of research. If we take a piece of bone, and having ground it so fine that we may examine it with transmitted light under the Microscope (Fig. 222, Pl. 8), we shall find it composed of a number of minute insect-shaped cells, surrounding an open canal. These cells, which are called *lacunæ*, and their little branches *canaliculi*, are modifications of the cells found in fishes' scales (Fig. 171, Pl. 6).

These curiously shaped cells differ in size and form in the various classes of animals belonging to the sub-kingdom *Vertebrata*, and thus a small portion

of a bone will frequently serve to indicate whether an animal belonged to fishes, reptiles, birds, or mammals. This is a matter of importance to the geologist in determining the character of the inhabitants of the earth at former periods of its history.

The shell of eggs seems to be formed on the same general principles as other hard parts, and the tendency to the formation of canaliculated cells may be easily observed (Fig. 177, Pl. 6). The young egg-shell should be examined (*a*), if the object is to study the history of the development of the shell ; and this may be compared on the one hand with the shells of the *Mollusca* and the *Crustacea*, and on the other hand with those of the scales, teeth, and bones of the vertebrate animals. Egg-shells present very different appearances. The shell of the emu, for instance, exhibits a series of dark triangular spots (Fig. 178, Pl. 6).

As one of the hard parts of animals, the structure of cartilage is very interesting. A slice may be obtained from the gristle of any young animal. Its structure is best seen in the mouse's ear (Fig. 221, Pl. 8). No one who looks at this object can but be struck with its resemblance to vegetable tissue ; and it was this resemblance which led to the application of the cell theory of development, which had been made out in vegetable structures, to those of animals.

Many of the soft parts of animal tissues afford instructive objects under the Microscope. If the tongue is scraped, and a drop of the saliva thus procured placed under the Microscope, it will be found to contain many flat, irregular, scale-like bodies with a nucleus in the centre (Fig. 4, Pl. 1). These scales are flattened cells, and closely re-

semble those found on the surface of the skin. Cells of a different kind line the air-passages. If a snip be taken from inside the nostril of a recently killed ox or sheep, it will be found to be composed of cells which are fringed with cilia at the top (Fig. 5, Pl. 1). These cilia are constantly moving, and produce the motion of the mucus on the surface of these passages which is essential to their healthy action.

The blood of animals presents us with objects of high interest. The human blood consists of a liquid in which float two kinds of cells. They are discoid bodies, from the one three thousandth to the three thousand five hundredth of an inch in diameter ($\frac{1}{3000}$ to $\frac{1}{3500}$) (Fig. 6, Pl. 1). They are of two sorts,—pale and red ; the latter are rather smaller, but are by far the most abundant. They present a little spot in the centre, which is called a *nucleus*, and this again another little spot, which is called a *nucleolus*. The red globules vary much in size and form in different animals. Thus, in birds, reptiles, and fishes, they are oval instead of round ; and, mostly, in these three classes much larger than in mammals. This is especially the case in the *batrachian* reptiles, to which the frog and toad belong (Fig. 8, Pl. 1). In the fowl (Fig. 7, Pl. 1), and in the sole (Fig. 9, Pl. 1), they are nearly twice as large as in man. In the insects they are also frequently of large size, as in the cockchafer (Fig. 10, Pl. 1).

The proof that blood-stains have been produced by human blood on articles of dress and other things, is frequently important in medico-legal investigations. Although it cannot be distinguished from all other kinds of blood, it may be from some ; and the Microscope has been employed as an adjunct in such cases.

The structure of the skin, and other organs of the body, are very interesting subjects for microscopical investigation; and volumes have been written upon their diversified details. The structure of voluntary and involuntary muscular tissue may be easily examined, especially the former, by taking a portion of the flesh of any animal usually eaten as food. The striated fibrillæ of voluntary muscle may be best seen in flesh cooked as food. A muscle consists of bundles of fibres, and each of these fibres consists of several fibrillæ lying close together. Each of these fibrils is seen to be crossed with lines (Fig. 223, Pl. 8), which indicate the point of union of the string of cells which form the ultimate parts of the muscular tissue.

We must now, however, draw our last half-hour to a close. All we have attempted has been in the way of introduction. We have only described those things which are most easily obtained, and we have sought rather to create a desire for further knowledge, than to impart an exhaustive amount of information on any one subject.

Those who have properly apprehended our remarks will see that there is not a distinct science of microscopic objects, but that these objects belong to various departments of science, whose great facts and principles must be studied from works devoted to them. The Microscope is in fact an instrument to assist the eyes in the investigation of the facts of structure and function, wherever they may occur in the great field of nature; and that inquirer must have a very limited view of the nature of science, who supposes either that the Microscope i the only instrument of research, or that any investigation, where its aid reveals new facts, can be successfully carried on without it.

APPENDIX.

BY THOMAS KETTERINGHAM.

THE PREPARATION AND MOUNTING OF OBJECTS.

THE majority of objects exhibited by the Microscope require some kind of preparation before they can be satisfactorily shown, or their form and structure properly made out. To convince the beginner of this, let him take the leg of any insect, and, without previous preparation, place it under his Microscope, and what does he see? A dark opaque body, fringed with hair, and exceedingly indistinct. But let him view the same object prepared and permanently mounted, and he will now regard it with delight. That beautiful limb, rendered transparent by the process it has undergone, now lies before him, rich in colour, wonderful in the delicate articulation of its joints, exquisite in its finish, armed at its extremities with two sharp claws equally serviceable for progression or aggression, and furnished, in many instances, with pads (*pulvilli*) (see Plate 7, Figures 198, 199), which enable the insect to walk with ease and safety on the smoothest surface. If the beginner has a true love for the study of the Microscope, he will be glad of information respecting the method pursued in dissecting and preserving microscopic objects, nor will he rest satisfied until he has acquired some knowledge of the art. We will briefly point out a few of the advantages possessed by those who are able to prepare specimens for themselves.

Objects well mounted will remain uninjured for years, and will continue to retain their colour and structure in all their original freshness.

They can be exhibited at all times to one's friends, and may be studied with advantage whenever an opportunity occurs.

By the practice of dissection such a knowledge is gained of the varied forms and internal organization of minute creatures as can be obtained in no other way.

There are doubtless many who, possessing a small Microscope, are unable by reason of their limited means to expend money in the purchase of ready-prepared specimens. To such a few plain directions, if followed, will be of service, and will enable them to prepare their own.

The materials necessary for the beginner are few, and not expensive. In fact, the fewer the better; for a multiplicity is apt only to cause confusion. The following will be found sufficient for all ordinary purposes, and may be obtained at any optician's.

Bottle of new Canada balsam.

Bottle of gold size.

Bottle of Brunswick black.

Spirits of turpentine—small quantity.

Spirits of wine—small quantity.

Solution of caustic potash (*liquor potassæ*).

Ether—a small bottle.

Empty pomatum-pots, with covers, for holding objects while in pickle.

Half a dozen needles mounted in handles of camel-hair brushes.

Pair of brass forceps.

Two small scalpels.

Pair of fine-pointed scissors.

Camel-hair pencils—half a dozen.

Slips of plate-glass, one inch by three inches—two dozen.

Thin glass covers, cut into squares and circles—half an ounce.

We will suppose that the beginner, having purchased the necessary materials, is about to make his first attempt. Let him attend to the following advice, and he will escape many failures.

He must bring to his work a mind cool and collected; hands clean and free from grease. Let him place everything he may require close at hand, or within his reach. A stock of clean slides and covers must always be ready for use. He must keep his needles, scissors, and scalpels scrupulously clean. An ingenious youth will readily construct for himself a box to contain all his tools. Cleanliness is so essential to success, that too much stress cannot be laid upon it. All fluids should be filtered and kept in well-corked phials. A bell-glass, which may be purchased for a few pence, will be

found exceedingly useful in covering an object when any delay takes place in the mounting. For want of it, many specimens have been spoilt by the intrusion of particles of dust, soot, and other foreign substances. Let the table on which the operator is at work be steady, and placed in a good light, and, if possible, in a room free from intrusion.

WINGS OF INSECTS.—Perhaps these are the easiest objects upon which the beginner can try his "prentice hand." Here little skill is required. Select a bee, or wasp, and with your fine scissors sever the wing from its body; wash it with a camel-hair brush in some warm water, and place it between two slips of glass, previously cleaned, which may be pressed together by a letter-clip, or an American clothes-peg; place it in a warm corner for a few days; when *quite dry*, remove it from between the slides, and soak it for a short time in spirits of turpentine. This fluid renders the object more transparent, frees it from air-bubbles, and prepares the way for a readier access of the balsam to the various portions of its structure.

Having selected from your stock a clean slide of the requisite size, and a thin glass cover somewhat larger than the object about to be mounted, hold them both up to the light, when any slight impurities will appear, and may be speedily removed by rubbing the surfaces of the glass with a fine cambric handkerchief, or a piece of soft wash-leather. Should, however, a speck or flaw in the glass itself be found in the centre of the slide, at once reject it and choose another. Remove the wing with a pair of forceps from the turpentine, and place it in the exact centre of the slide; this may be accomplished by cutting a stiff piece of card-board, tin, or zinc, the size of the slide, and punching a hole, the edge of which should be equally distant from each end and each side; lay the slide upon it, and place the object in the circular space; you will thus get it properly centred.

Before dropping the balsam (which should have been previously warmed) upon the specimen, place it under the Microscope: you may possibly detect some foreign substance, in the shape of a particle of soot or a fibre from your handkerchief, in contact with it; remove it with the point of a needle. Take up a small quantity of the balsam on the end of a small glass rod, and let it fall upon the object; hold the slide for a few minutes over the flame of a candle or spirit-lamp at a distance sufficient to make it warm, but not hot; the balsam will gradually spread itself over and around the

object: should air-bubbles arise, they may be broken by touching them with the point of a needle; they will, however, frequently disperse of themselves as the balsam dries. The thin glass cover, being warmed, should now be placed upon the object, and a slight pressure applied to get rid of the superfluous balsam. Place the slide in some warm spot to dry; an oven will do very well, if the fire has been some time removed and there is not sufficient heat to make the balsam boil.

In a short time the balsam round the edges of the cover will be hard enough to admit of the greater part being scraped off with a knife; the remainder may be got rid of by wiping the slide with a rag dipped in turpentine or ether. The finishing touch consists in labelling the object with its proper name. It will be found advantageous to place the common name of the specimen at one end of the slide, and its scientific name at the other.

Some persons prefer covering their slides with ornamental paper, which may be obtained of almost any optician. Others prefer the glass without any covering at all. In the latter case the edges of the slide should be ground, the round thin glass covers used, and the name scratched upon the slide with a writing diamond. In the former, the edges of the slide, being covered with paper, need not be ground, but square thin covers should be used instead of round ones, and the name written with pen and ink in the square places allotted at each end of the slide.

Legs of Insects (Plate 7, Figs. 198, 199, 200; Pl. 8, Figs. 208, *a*, *b*, *c*; Fig. 209, *a*, *b*; Figs. 213, 214).—These require a little more preparation than wings; and as they possess some thickness, and are mostly opaque, besides being of a hard, horny character, they should be placed for a fortnight or even longer in *liquor potassæ*: this will soften the tissue and dissolve the muscles and other matter contained within them, so that by gently pressing the limb between two slips of glass the interior substance will gradually escape, and may be removed by repeated washings. The squeezing process, however, must be conducted gently, to prevent any rupture: perhaps the best plan is to plunge the slips of glass into a basin of clean water, when all impurities oozing out from the pressure will sink to the bottom. Should the leg not be sufficiently softened to be squeezed quite flat, it must be again placed in the solution for a longer period, until this result be obtained. On removing it from the potash it should be well washed with

a camel-hair pencil in clean water, placed between two slips, held together by an American clothes-peg with a good stiff spring. If placed in a warm corner, a few days will be sufficient to dry it thoroughly: afterwards soak it in spirits of turpentine; the time of immersion to be regulated by the opacity of the object.

The directions for mounting in balsam are precisely the same as those given for the wings of insects. Care should be taken not to heat the balsam too hot, as it will invariably destroy delicate specimens by curling them up. In tough horny structures, such as the wing-cases of beetles, &c., heat is sometimes an advantage, and there are a few structures that show to advantage when the balsam has been heated to a boiling pitch; but for the majority of objects a gentle warmth is all that is required.

Ovipositors and Stings (Plate 7, Fig. 193) are more difficult to prepare, and require some amount of dissection before they can be properly displayed. To do this, some degree of skill is necessary and a knowledge of insect anatomy, which can be acquired only by study and practice. As a rule, all dissection should be carried on as far as possible with the naked eye; when this has been accomplished, we must then seek the aid of lenses.

The object-glasses of one's Microscope are the best that can be used for the purpose. An inch lens will be found especially fitted for the work. A simple Microscope, provided with a broad stage, and an arm movable by rack and pinion for carrying the lenses, is the kind of instrument usually employed. It should be strongly made, and capable of bearing a good deal of rough usage.

Dissections may be carried on under the compound Microscope; but we do not think the beginner would succeed, as all objects in motion seen through this instrument are inverted. If, however, he be provided with an erector, this difficulty is overcome by the object being brought into the same position that it occupies when seen by the naked eye.

As most dissections are carried on under water, some kind of shallow trough is necessary to contain it: watch-glasses answer the purpose remarkably well. The small white dishes and covers used for rubbing up colours will be found very useful; also some cork bungs ou which to pin the object; and these last should have their under sides loaded with lead to sink them in fluid. A great many delicate dissections may, however, be made in a drop of water placed

on a slip of glass ; but for all objects of large size, the trough, or some similar contrivance, will be necessary.

All insects that have been killed a long time, and whose bodies are hard and brittle, may be softened by immersing them in the solution already mentioned.

The sting of the bee, wasp, hornet, and the ovipositors of many flies, especially the ichneumons, are very similar in their structure, and are generally found at the termination of the abdomen, from which they may be obtained by first slitting open the body of the insect with the fine scissors, and afterwards removing the sting by using the scalpel and needles. One or two of the latter should have their points curved, which may easily be accomplished by heating the ends red-hot in the flame of a candle, and bending them with a pair of small pincers. At first sight the sting presents nothing to the eye but a horny sheath, tapering to a point, with a slit broadest at its base and running down the entire length ; within this sheath, on each side, lies a barbed sharp-pointed spear in large insects, capable of inflicting a severe wound, while the tube in which they are lodged acts as a steadying rod, and as a channel to conduct a virulent poison to the wound. The bag containing the poison is placed at the root of the sting, and is connected by a narrow neck with the sheath. The difficulty in the dissection of the sting lies in getting the barbed points out of the sheath and placing them on each side of it. The following is the method employed by the writer. The sting is placed in potash until it loses some of its rigidity ; it is then transferred to a slip of glass or earthenware trough. The curved needle-points are essential here. With one hold the object firmly on the stage of the Microscope, insert the point of the other into the opening at the base of the sheath where it is largest, and gradually draw the point down the tube ; this will make the opening wider and dislodge the barbs ; arrange them on each side of the sheath, place the sting between two glass slips subject to pressure. When dry, soak it for a few days in turpentine, and mount in balsam in the usual manner. A good specimen ought to show the barbs very distinctly on each side of the sheath.

It will be found useful to the student to prepare three specimens of this organ :—

1st. The whole abdomen showing the position the sting occupies within it.

2nd. The sting with the barbs lying within the sheath.

3rd. The barbs pulled out of the sheath and placed on each side of it.

Three such specimens well mounted will enable the student to study the structure of this curious organ with advantage.

SPIRACLES (Plate 7, Figs. 205, 206).—These do not require much dissection. They are generally found on each side of the abdomen, almost every segment of which possesses a pair. Excellent specimens are furnished by the dytiscus, bee, blowfly, cockchafer, and silkworm. To prepare them, separate from the thorax the abdominal portion of the insect, and slit it down the centre with the fine-pointed scissors, draw out the viscera, &c., with the curved needles. The air-tubes adhering to the spiracles may be detached by cutting them away with the scissors. Thoroughly cleanse the horny cuticle by repeated washings, spread it out flat between two slips of glass; when dry, immerse it in spirits of wine or turpentine for a few days, and mount it in balsam. In this manner the whole of the spiracles of an insect, running down each side of the abdomen, will be displayed.

TRACHEÆ (Plate 8, Fig. 212).—The best method we are acquainted with for obtaining the air-tubes of insects is that recommended by Professor Quekett:—

"By far the most simple method of procuring a perfect system of tracheal tubes from the larva of an insect, is to make a small opening in its body, and then to place it in strong acetic acid: this will soften or decompose all the viscera, and the tracheæ may then be well washed with the syringe, and removed from the body with the greatest facility, by cutting away the connections of the main tubes with the spiracles by means of the fine-pointed scissors. In order to get them upon the slide, this must be put into the fluid and the tracheæ floated upon it, after which they may be laid out in their proper position, then dried, and mounted in balsam."

The best specimens are found in the larva of the dytiscus and cockchafer, and in the blowfly, goat-moth, silkworm, and house-cricket.

GIZZARDS (Plate 8, Figs. 210, *a, b*; 211, *a, b*).—Most of the insects from which these organs are procured being of large size, it will be necessary to secure them to one of the loaded corks by small pins. The dissection should be made in one of the shallow troughs, filled with weak spirit and water. Cut the insect open; the stomach will float out with the gizzard attached to it, in the shape of a small

bulbous expansion of the size of a pea. Insert the fine point of the scissors and cut it open; the interior will be found full of food in process of trituration. Empty the contents of the gizzard, and wash it out well; place it for a few days in the solution of potash; and, finally, cleanse it with some warm water and a camel-hair brush. Spread it out flat between slips of glass; when dry, place it in turpentine for a week, and afterwards mount it in balsam.

The best specimens for displaying the horny teeth with which the gizzard is furnished are obtained from crickets, grasshoppers, and cockroaches.

Palates (Plate 6, Figs. 167, 168, 169, 170).—These consist of a narrow kind of tongue, armed with a series of horny teeth, placed in regular rows. The whelk, limpet, periwinkle, garden-snail, and the snails found in our cellars and aquariums, are all furnished with this peculiar apparatus, which may be obtained by laying open the body with the scalpel or scissors. It will generally be found curled up near the head, and may be distinguished by its ribbon-like appearance: patience and skill are necessary to extract it from the surrounding mass. When properly cleaned, it may be at once pressed flat and dried between slips of glass. Many palates polarize well when mounted in balsam; but if not intended for polarization, they should be mounted in a preservative fluid, composed of five grains of salt to one ounce of water.

Tongues, Probosces, Mandibles, and Antennæ (Plate 7, Figs. 189—192, 194—197) are amongst the most beautiful objects exhibited by the Microscope. Many of these, besides the ligula, possess several sharp lancets for puncturing the skin of animals from whom they derive their sustenance. To arrange these organs so that each part may be clearly seen, requires a good deal of delicate manipulation. It is generally more satisfactory to mount the whole head of the insect. To accomplish this, it must be softened by immersion in *liquor potassæ* for some time, and the interior substance got rid of by pressure. To dry it flat, place it between two slips of glass, which should be held together by a spring-clip; soak it for a fortnight or longer in turpentine, until it becomes transparent, and then mount it in balsam.

The head of the bee, wasp, dronefly, blowfly, and gadfly, are all excellent examples of the varied structures of these suctorial organs.

Eyes (Plate 7, Figs. 201, 201*a*, 203).—The compound

eyes of insects, for the display of their numerous facets, should be dissected from the head, and macerated in fluid. The black pigment lining the interior may be got rid of by washing it away with a camel-hair brush. When quite clean, the cornea may be dried and flattened between two slips of glass. In practice, however, the cornea, from its sphericity, will be found to have a tendency to fold in plaits, or to split in halves. To remedy this, cut with the fine scissors a few notches round its edges ; it may then be flattened without danger of its either wrinkling or splitting. When the cornea is very transparent, it should be mounted in a cell with some kind of preservative fluid (spirit and water will do very well), otherwise the structure will be lost if mounted in balsam, the tendency of that substance being to add transparency to every object with which it comes in contact. But there are many insects in whose eyes the hexagonal facets are strongly marked : all such will show best when mounted in balsam.

HAIRS (Plate 7, Figs. 179 to 186).—These may be mounted either in fluid or balsam, first taking the precaution to cleanse them from fatty matter by placing them in ether. If the hair be coarse and opaque, mount it in balsam ; if fine and transparent, it should be mounted in a cell, with some weak spirit.

Sections of hair are made by gluing hairs into a bundle, and placing it in a machine for making sections. By means of a sharp knife which traverses the surface, the thinnest slices may be cut, and each individual section afterwards can be separated in fluid. To select the thinnest and best, place them under the Microscope. The point of a camel-hair pencil will be found the best instrument for transferring them to a clean slide. When dry, mount them in balsam, as usual. Some very good sections of the hairs of the beard may be obtained by passing the razor over the face a few minutes after having shaved.

SCALES OF FISH (Plate 6, Figs. 171 to 176).—These dermal appendages may be detached from the skin by a knife ; and if to be viewed as opaque objects, may be dried and mounted with no other preparation than cementing over them a thin glass cover. If intended to be viewed as transparent objects, the scales should be properly cleaned, dried, and mounted in balsam ; but the most satisfactory way of exhibiting their structure is to mount them in a cell with some preservative fluid.

SCALES OF BUTTERFLIES, MOTHS, &c. (Plate 8, Figs. 215

to 219).—Select the wing of a living or recently-killed insect, gently press it on the centre of a clean glass slide. On removing the wing, numerous scales will be seen adhering to the slide ; place over them one of the thin glass covers, and cement it down by tipping lightly the edges with gold size. Specimens should be taken from various parts of the wings of the same insect, as the form of the scales vary according to the position they occupy in the wing.

SECTIONS OF BONE (Plate 8, Fig. 22).—All hard and brittle substances from which thin slices cannot be made by a sharp knife, must be reduced to a transparent thinness by the process of grinding down. Having selected the bone from which the section is about to be made, a thin slice should be cut from it with a fine saw. At first the section may be held by the fingers while grinding down one of its surfaces on a coarse stone ; but when it approaches the thinness of a shilling, it must be cemented by some old and tough Canada balsam to a slip of glass. Upon the perfect adhesion of the section to the slide depends in a great measure the success of the operation. Having reduced the thickness of the section by a coarse stone or a file, transfer it to a hone ; a few turns will obliterate scratches, and produce an even, smooth surface, which may be further polished by rubbing it on a buff-leather strop charged with putty-powder and water. When dry, attach the polished surface to the glass slip : this gives a firm hold of the section, which would otherwise become too thin to be held by the fingers. In rubbing down the unfinished surface, take care that an equal thickness prevails throughout the section. As it approaches completion, recourse must be frequently had to the Microscope, in order to determine how much further it is necessary to proceed, a few turns either way at this stage being sufficient to make or mar the specimen. When it has become so transparent that objects may be readily seen though it, remove it from the hone and polish it on the strop. To detach it from the slide when finished, place it in turpentine or ether, both being excellent solvents of balsam. Mount in the dry method, by simply cementing a thin glass cover over it. In recent bone, this method of mounting, though the most difficult, is decidedly the best for displaying its structure. Fossil bone, however, where the interstices are filled with earthy matter, shows best in balsam.

SPINES OF THE ECHINUS (Plate 5, Fig. 149) ; SECTIONS OF SHELL (Plate 6, Figs. 161 to 166).—These are cut and reduced in the same manner as sections of bone ; but they

require greater care in grinding, in consequence of being more brittle. The polishing, however, may be dispensed with, and the section mounted in balsam.

STONES OF VARIOUS KINDS OF FRUITS (Plate 8, Fig. 232) will well repay the labour bestowed in producing good sections. The saw, the file, and the hone are the principal agents used in the reduction of these hard osseous-like tissues. A perfect section should have but one layer of cells, which may be admirably seen when mounted in a cell with weak spirit.

SECTIONS OF WOOD (Plate 3, Figs. 49 to 55).—To make thin sections of hard wood it will be necessary to employ some kind of cutting-machine. There are several of these, more or less expensive, but the principle of construction in all is similar. The wood, after some preparation, and being cut to the requisite length, is driven by a mallet into a brass cylinder, at the bottom of which works a fine screw with a milled head. The wood is pushed to the surface of the tube, and to any degree above it by the revolution of the screw; when a sharp knife, ground flat on one side, is brought with a sliding motion in contact with it. The slices may be removed from the knife by a wetted camel-hair pencil, placed in some weak spirit, and examined at leisure; the thinnest and most perfect section being retained for mounting. Green wood previous to being cut should be placed in alcohol and afterwards in water. Hard and dry wood may be made sufficiently soft for slicing by first immersing it in water for some days. Sections of the above may be mounted either in balsam or fluids. Stems of plants, horny tissues, and many other substances not sufficiently hard to be ground down, may be cut into slices of extreme thinness by this handy instrument.

CUTICLE OF PLANTS (Plate 2, Figs. 37 to 41), HAIRS (Plate 3, Figs. 69 to 82), AND SPIRAL VESSELS (Plate 2, Figs. 42 to 45), may all be obtained by macerating the leaves and stems of plants in water, and afterwards dissecting them with the needles. Good specimens of the cuticle, showing the stomata, may be often obtained by simply peeling off the skin with a sharp knife. Hairs may be detached from various parts of a plant by a similar process. Spiral vessels will, however, require to be separated by the needles from the surrounding tissues. All delicate vegetable preparations are best displayed when mounted in a cell with weak spirit.

Cells for mounting objects in fluid are generally formed of some kind of varnish upon which the fluid will not act:

gold size and Brunswick black are most commonly used. To form a cell, simply charge a camel-hair brush with the varnish, and enclose with a broad black ring a small circular space on the centre of the slide. When quite dry, it is ready for use. Place the object, with a small quantity of fluid, in the cell; and having lightly touched the edges of the thin glass cover with gold size, drop it gently on the specimen; the superfluous fluid will escape over the sides of the cell, and may be removed by small pieces of blotting-paper, taking care, however, that none of the fluid is drawn from the interior of the cell; in which case an air-bubble would immediately appear. To make the cell air-tight, gradually fill up the angle formed by the edges of the cover with the cell, by running several rims of varnish round it. In order to prevent the cement from running into the cell and spoiling the specimen, each layer should be dry before another is placed upon it.

The student should always have a stock of cells on hand ready for immediate use. Dozens of these cells may be made in half an hour by an ingenious little turntable, the invention of Mr. Shadbolt, and which may be obtained for a few shillings.

The limits of this little work have precluded us from giving little more than general directions respecting the permanent preparation of microscopic objects. Our object has been merely to give a few plain instructions, which, if carefully followed, will enable him to prepare some of the most popular objects exhibited by the Microscope.

THE END.

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